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Distribution of *Corbicula fluminea* at Nuclear Facilities

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Prepared for
U.S. Nuclear Regulatory
Commission

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Distribution of *Corbicula fluminea* at Nuclear Facilities

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ABSTRACT

A review of the zoogeographic records for the exotic Asian clam, Corbicula fluminea (Muller, 1774), reveals its presence in 27 states where nuclear powered electric generating plants are either operating or under construction. Nineteen plant sites reported infestation of varying severity in facilities, or source water bodies immediately adjacent to the facility, by C. fluminea. Thirteen plant sites are located within the zoogeographic limits of C. fluminea but have a low risk of infestation due to either salt water cooling systems or locations a great distance from known populations. Eighteen plant sites are located wholly outside of the known zoogeographic range of C. fluminea. Thirty plant sites are located in close proximity to known populations of C. fluminea and therefore should maintain surveillance of the source water body and within plant water systems for possible infestations by these bivalves.

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REVIEW OF CORBICULA FLUMINEA AT NUCLEAR FACILITIES

1.0 INTRODUCTION

In accordance with the Statement of Work in Task Order 1 under Contract NRC-03-84-063, this report provides documentation for the zoogeographic distribution of the exotic Asiatic bivalve, Corbicula fluminea (Muller 1774) at or near nuclear powered electric generating stations.

1.1 BACKGROUND

Corbicula fluminea was introduced into North America sometime during or before the 1920's (Counts 1981a). Our earliest record for C. fluminea is at Nanaimo, Vancouver Island, British Columbia and was collected in 1924. The first published account of C. fluminea in the United States is that of Burch (1944) for specimens collected along the banks tidal portion of the Columbia River near Knappton, Pacific County, Washington in 1938. C. fluminea was collected in 1937 at Raymond, Pacific County, Washington (Counts 1985). Since these initial discoveries, C. fluminea has invaded nearly every major river system of the United States and now appears in the western Great Lakes drainage (Clarke 1981).

In the late 1940's and early 1950's, Corbicula fluminea invaded the San Francisco Bay estuary and the Delta-Mendota Canal of California's Central Valley. C. fluminea was responsible for fouling of pump cooling condensers at the Tracy Pumping Plant of the canal and this infestation resulted in extensive repair and replacement of components in the plant (Eng 1979). C. fluminea was also reported to foul irrigation systems in Arizona (Ingram 1959). These fouling problems have extended to power generating facilities.

In September 1980, Arkansas Nuclear One, Unit 2 (Docket No. 50-368) failed to meet minimum service water flow rate through the containment cooling units. The plant was shutdown and it was found that flow rates were impeded by extensive fouling of the containment cooling units by the exotic Asiatic bivalve Corbicula fluminea. Upon disassembly of the service water piping at the inlet to the coolers, clams were found in the three inch diameter supply piping at the inlet to the containment cooling units and in the cooler inlet water boxes. Size of the fouling clams ranged from larval sizes to 1 inch. Some of these bivalves were living. Inspection of other components of the service water system of Units 1 and 2 revealed fouling and plugging of seal water coolers for both redundant containment spray pumps and one low pressure safety injection pump from silt, corrosion products, and debris composed mostly of clam shell pieces. The high pressure safety injection pump bearing and seal coolers were also extensively fouled in the 0.5 inch pipe service water supply lines. Clam shells were also found in some of the auxiliary building room coolers and in the auxiliary cooling water system that serves non-safety related equipment.

This event prompted the issuance, on 10 April 1981, of U.S. Nuclear Regulatory Commission Office of Inspection and Enforcement Bulletin 81-03, Flow Blockage of Cooling Water to Safety System Components by Corbicula sp. (Asiatic Clam) and Mytilus sp. (Mussel). The bulletin required holders of operating licenses to 1) determine the presence of Corbicula fluminea in the vicinity of the station in either the source or receiving water body, 2) confirm the presence or absence of these bivalves, as entire animals or as shell debris, in fire protection systems or systems that directly circulate water from the station source water body, 3) measure flow rates through affected or potentially affected safety related water systems, 4) describe plans for the detection and prevention of blockage by clams, and 5) describe the actions taken by the plant to determine the presence of fouling bivalves, the components affected, results of environmental sampling, the extent of fouling if it existed, how the fouling was discovered, and the corrective or preventative actions taken.

Holders of construction permits were also required to determine the presence or absence of Corbicula fluminea in the vicinity of the plant and to determine the safety related systems which could be fouled. Construction permit holders were also required to list those systems already affected, the extent of the fouling, how and when fouling was discovered, and any corrective or preventative actions taken.

While the responses to IE Bulletin 81-03 did provide information on the presence of Corbicula fluminea at specific plant sites, nearly all of the responses were uninformed as to the actual extent of the species biogeographic distribution in their state. This was due, in large measure, to the practice of sampling source waters for plants only at the plant site without making extensive collection upstream or downstream of the facility.

Only one published report on the biogeography of C. fluminea in the United States has appeared (McMahon 1982). That report, however, was more concerned with the history of the invasion of United States waters by C. fluminea than giving precise localities for known populations. Counts (1983, 1985) provided these localities for each of the 32 affected states. These data were assembled into a computerized base and represent the largest single source of information on the zoogeographic distribution of C. fluminea in the United States.

Therefore, the following study was performed in an effort to determine the actual extent of Corbicula fluminea distribution in relation to nuclear facilities and to identify those facilities that may experience future fouling problems from this bivalve.

1.2 BIOLOGY OF CORBICULA FLUMINEA

While the biology of Corbicula fluminea is beyond the scope of the present report, it is an important factor in the ability of these bivalves to successfully infest industrial facilities. Hence, a brief review of the biology of C. fluminea in the United States is presented below.

Corbicula fluminea inhabits fresh to brackish water. These bivalves are simultaneous hermaphrodites (i.e. both male and female reproductive organs are present in a single individual). It is believed that C. fluminea is capable of self-fertilization.

The Asiatic clam in North America, in most instances, has two spawning periods a year with peak spawning activity occurring in the spring and fall. A combination of environmental factors has been identified as stimulating these bivalves to spawn. The most important of these are the availability of food and water temperature. Spawning activity (i.e. the release from the reproductive organs of gametes) is initiated as water temperatures rise above or fall below 18-19 C (range = 16-21 C). Larval clams produced during the spawning periods are brooded in the gills of the parent clam for about 30 days and are released as juveniles; essentially miniature adults. These larvae measure from 0.22 - 0.27 mm upon release from the parent. A single adult bivalve releases approximately 8,000 juveniles per year.

In two studies, larvae were reported in the first study to be meroplanktonic (Sinclair and Isom, 1961) and, in the second study, to be swimming at the water column surface (Sinclair and Isom, 1963). However, most studies reveal the larvae are released as advanced juveniles that are benthic and incapable of swimming. Recent work by Prezant and Chalermwat (1984) revealed Corbicula fluminea produces a mucus "drogue" that allows it to become suspended in the water column and thus be transported great distances downstream. It is during the juvenile stage that entrainment into power plant cooling systems is most likely to occur. This is due to the small size of the juvenile and its ability to become entrained in water currents.

Pediveliger larvae spawned during the early spring (April) will be sexually mature by the fall (September - October). Larvae spawned during the fall will be sexually mature in the spring.

Corbicula fluminea have been found in virtually all substrata types in densities usually ranging between 1,000 to 12,000 clams per square meter. The highest density reported for these bivalves was 131,000 clams per square meter in the Delta - Mendota Canal of California.

Standard references for the biology and ecology of Corbicula fluminea in the United States include works by Sinclair and Isom (1961, 1963), Britton and Morton (1982), and McMahon (1983). The biogeography of C. fluminea is discussed by Counts (1983, 1985). Also, the Proceedings of the First International Corbicula Symposium (1979) is a valuable reference on several aspects of C. fluminea biology and ecology and on bio-fouling potential of the species.

2.0 TAXONOMY

There is some debate as to how many species of bivalves in the genus Corbicula are currently present in the United States. Corbicula clams in this country have been reported using the taxa Corbicula fluminea, Corbicula leana Prime, 1984, Corbicula manilensis (Philippi 1844), and Corbicula sinensis (nomen dubium). While McLeod and Salstad (1980) and Hillis and Patton (1982) have presented electrophoretic evidence for two species in Texas waters, their studies are as yet inconclusive. Thus, the taxon C. fluminea, sensu Britton and Morton (1979), will be used for all populations of corbiculid bivalves discussed in this report.

3.0 METHODS

Zoogeographic records for Corbicula fluminea, obtained from the malacological collections of the institutions, state agencies, and private individuals listed in Table 1, and contained in the computerized data base at the University of Delaware College of Marine Studies (UD/CMS) were collated with the available literature (Counts 1983). Categories of information encoded are month and year of collection of first report of the population, body of water infested, state, county, nearest city to population site, locations and catalog numbers of museum specimens, literature report citations, and geographic coordinates. Records were then sorted by state.

All records were assembled into individual state accounts, reviewing the available literature and demonstrating the zoogeographic distribution of Corbicula fluminea in relation to nuclear facilities. Biogeographic distribution of C. fluminea was plotted on base stream maps for each state along with the locations of extant and planned nuclear facilities.

A review of utility responses to I & E Bulletin 81-03, Flow Blockage of Cooling Water to Safety System Components by Corbicula sp. (Asiatic Clam) and Mytilus sp. (Mussel), was also conducted to ascertain those facilities that have experienced fouling problems with these bivalves.

Nuclear powered electric generating stations were then categorized on the basis of their proximity to populations of Corbicula fluminea. Four (4) categories were established:

1. Facilities at which Corbicula fluminea is known to occur either within the plant or in the water source for the cooling system immediately adjacent to the facility.
2. Facilities located in close proximity to populations of Corbicula fluminea and thus have a high potential for infestation. Close proximity does not necessarily mean the presence of C. fluminea in the cooling system water source.
3. Facilities located within the overall zoogeographic range of Corbicula fluminea but who have a low potential for infestation due to the use of salt water cooling systems or location great distances away from known populations.

4. Facilities located wholly outside of the known zoogeographic range of Corbicula fluminea and thus have no present risk of infestation.

4.0 NUCLEAR FACILITIES AND CORBICULA FLUMINEA INFESTATION

The present report differs from that of Rains et al. (1984) in that, while utility responses to IE Bulletin 81-03 were reviewed and included, zoogeographic records for Corbicula fluminea in institutional, industrial, private, and governmental collections and literature records were also used to assess the accuracy of responses to the bulletin. The use of the UD/CMS data base also permitted a more accurate assessment of those facilities that may encounter fouling by C. fluminea in the future. A detailed account of C. fluminea for each state in the five NRC regions that have nuclear powered electric generating stations and populations of C. fluminea is given in Section 6.0.

Table 2 lists those nuclear facilities at which Corbicula fluminea is found either in the facility or in the cooling system source water immediately adjacent to the facility. These stations should continue frequent periodic inspection of water systems to detect intrusion of C. fluminea into the plant as well as for evidence of fouling. Further, it is recommended that studies of reproductive seasonality be conducted on populations adjacent to these facilities so that timely application of biocides can be effected.

Facilities located in close proximity to populations of Corbicula fluminea and thus having a high potential for infestation are listed in Table 3. The facilities included in Table 3 do not exactly agree with those in the high risk category of Rains et al. (1984). This is due in part to the ability of the present study to compare nuclear facility locations with the zoogeographic data base for C. fluminea. An explanation of the inclusion of facilities in this list appears below.

Bellefonte Units 1 and 2 (Docket Nos. 50-438, 50-439) are located on the Tennessee River. The serious, long-standing infestation of this river by Corbicula fluminea warrants frequent monitoring of the river within 10 miles of the plant to ensure early detection. Upon detection, studies of reproductive periodicity should be undertaken to determine the time of year when larval entrainment is most likely to occur and thereby permitting timely application of biocides.

Braidwood 1 and 2 (Docket Nos. 50-456, 50-457) and LaSalle 1 and 2 (Docket Nos. 50-373, 50-347) are located on the Kankakee River. The infestation of this river and nearby Dresden Power Plant Units 1, 2, and 3 (Docket Nos. 50-010, 50-237, 50-249) by Corbicula fluminea warrant monitoring of the river and plant in the manner described above for Bellefonte.

Table 1. Malacological collections represented in the University of Delaware/College of Marine Studies (UD/CMS) data base for Corbicula fluminea.

Museums:

Academy of Natural Sciences of Philadelphia
 California Academy of Sciences, San Francisco
 Cincinnati Museum of Natural History
 Delaware Museum of Natural History
 Field Museum of Natural History, Chicago
 Florida State Museum, University of Florida
 Fort Worth Museum of Science and History
 Houston Museum of Natural Science
 Illinois State Museum, Springfield
 Marshall University Malacological Collection,
 Huntington, West Virginia
 Los Angeles County Museum of Natural History
 Milwaukee Public Museum
 Mississippi Museum of Natural Science, Jackson
 Museum of Comparative Zoology, Harvard University
 Museum of Northern Arizona, Flagstaff
 National Museums of Natural Science, Ottawa, Canada
 North Carolina State Museum of Natural History, Raleigh
 The Ohio State University Museum of Zoology, Columbus
 Peabody Museum of Natural History, Yale University
 San Diego Museum of Natural History
 Stanford University Museum
 State Biological Survey of Kansas, Lawrence
 Thomas Burke Memorial Washington State Museum,
 University of Washington
 United States National Museum of Natural History
 University of Cincinnati Geological Museum
 University of Oklahoma Museum, Norman

State Agencies:

Arkansas Department of Pollution Control
 Illinois Natural History Survey
 Missouri Department of Conservation
 Oregon Department of Fish and Wildlife

Private Collectors or Industrial Sources:

R. Tucker Abbott, American Malacologists
 E. Constance Boone, Houston Museum of Natural Science
 Robert Bullock, University of Rhode Island
 Steven L. Coon, University of Maryland
 Gary A. Coover, Toledo, Ohio
 James J. Hall, Duke Power Company
 Stavros R. Howe, University of Delaware
 Russell Jensen, Delaware Museum of Natural History
 David Metty, Cincinnati, Ohio
 Richard L. Reeder, University of Tulsa

Table 2. Nuclear facilities at which *Corbicula fluminea* is found either in the plant or in the source water body immediately adjacent to the plant site. Facility status is derived from Summary Information Report, June 1984. See Section 5.0 for abbreviations.

Facility	Docket No.	Region	Status
Arkansas 1	50-313	IV	OL
Arkansas 2	50-368	IV	OL
Beaver Valley 1	50-334	I	OL
Beaver Valley 2	50-412	I	CP
Browns Ferry 1	50-259	II	OL
Browns Ferry 2	50-260	II	OL
Browns Ferry 3	50-296	II	OL
Catawba 1	50-413	II	CP
Catawba 2	50-414	II	CP
Dresden 1	50-010	III	SDI
Dresden 2	50-237	III	OL
Dresden 3	50-249	III	OL
Farley 1	50-348	II	OL
Farley 2	50-364	II	OL
Hatch 1	50-321	II	OL
Hatch 2	50-366	II	OL
Hartsville A1	50-518	II	CHI
Hartsville A2	50-519	II	CHI
Hartsville B1	50-520	II	CD
Hartsville B2	50-521	II	CD
McGuire 1	50-369	II	OL
McGuire 2	50-370	II	OL
North Anna 1	50-338	II	OL
North Anna 2	50-339	II	OL
North Anna 3	50-404	II	CD
Oconee 1	50-269	II	OL
Oconee 2	50-270	II	OL
Oconee 3	50-287	II	OL
Phipps Bend 1	50-553	II	CD
Phipps Bend 2	50-554	II	CD
Quad Cities 1	50-254	III	OL
Quad Cities 2	50-265	III	OL
Sequoyah 1	50-327	II	OL
Sequoyah 2	50-328	II	OL
South Texas 1	50-498	IV	CP
South Texas 2	50-499	IV	CP
Summer 1	50-395	II	OL
Trojan	50-344	V	OL
Vogtle 1	50-424	II	CP
Vogtle 2	50-425	II	CP
Waierford 3	50-382	IV	OL
Watts Bar 1	50-390	II	CP
Watts Bar 2	50-391	II	CP

Table 3. Nuclear facilities located in close proximity to populations of Corbicula fluminea and who should maintain surveillance of the source water body and within the plant for infestations by these bivalves. Facility status is derived from Summary Information Report, June 1984. See Section 5.0 for abbreviations.

Facility	Docket No.	Region	Status
Bellefonte 1	50-438	II	CP
Bellefonte 2	50-439	II	CP
Braidwood 1	50-456	III	CP
Braidwood 2	50-457	III	CP
Brunswick 1	50-325	II	OL
Brunswick 2	50-324	II	OL
Callaway 1	50-483	III	CP
Clinton 1	50-461	III	CP
Comanche Peak 1	50-445	IV	CP
Comanche Peak 2	50-446	IV	CP
Crystal River 3	50-302	II	OL
Davis Besse 1	50-346	III	OL
Duane Arnold	50-331	III	OL
Fermi 2	50-341	III	CP
Grand Gulf 1	50-416	II	LPTL
Harris 1	50-400	II	CP
Harris 2	50-401	II	CP
Hope Creek 1	50-354	I	CP
LaCrosse	50-409	III	OL
LaSalle 1	50-373	III	OL
LaSalle 2	50-374	III	CP
Limerick 1	50-352	I	CP
Limerick 2	50-353	I	CP
Monticello	50-263	III	OL
Palo Verde 1	50-528	V	CP
Palo Verde 2	50-529	V	CP
Palo Verde 3	50-530	V	CP
Peach Bottom 2	50-277	I	OL
Peach Bottom 3	50-278	I	OL
Prairie Island 1	50-282	III	OL
Prairie Island 2	50-302	III	OL
Rancho Seco 1	50-312	V	OL
River Bend 1	50-458	IV	CP
Robinson 2	50-261	II	OL
Salem 1	50-272	I	OL
Salem 2	50-311	I	OL
San Onofre 1	50-206	V	OL
San Onofre 2	50-361	V	OL
San Onofre 3	50-362	V	OL
Surry 1	50-280	II	OL
Surry 2	50-281	II	OL

Table 3. (Concluded)

Facility	Docket No.	Region	Status
Susquehanna 1	50-387	I	OL
Susquehanna 2	50-388	I	CP
TMI 1	50-289	I	OL
TMI 2	50-320	I	SDI
WNP 1	50-460	V	CHI
WNP 2	50-397	V	OL
WNP 3	50-508	V	CP

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The Cape Fear River, on which Brunswick 1 and 2 (Docket Nos. 50-324, 50-325) and Harris 1 and 2 (Docket Nos. 50-400, 50-401) are located is infested by Corbicula fluminea. The Harris facility is located in close proximity to several populations and should continue surveillance for these bivalves. In view of C. fluminea's ability to withstand high salinity environments for short periods, as in tidal waters, as well as demonstrated long-distance transport during periods of high stream flow (Prezant and Chalermwat 1984), the Brunswick facility should continue monitoring for the presence of these bivalves.

Callaway Unit 1 (Docket No. 50-483) should continue surveillance for Corbicula fluminea since many populations of these bivalves have been identified in the Missouri, Osage, and Gasconade Rivers.

Corbicula fluminea is in close proximity to Clinton 1 and 2 (Docket Nos. 50-461, 50-462). The Illinois River system is heavily infested throughout its length by these bivalves and thus continued monitoring of the Salt River and Clinton Lake is recommended.

The long-standing infestation of the Brazos River system as well as Lake Granbury by Corbicula fluminea warrants stream monitoring at the Comanche Peak Station Units 1 and 2 (Docket Nos. 50-445, 50-446). Monitoring of the streams in the area surrounding the facility is also recommended.

Crystal River Unit 3 (Docket No. 50-302), although located on the Gulf of Mexico, is also located amid several populations of Corbicula fluminea. Therefore, the plant should continue to monitor water systems using freshwater for the presence of C. fluminea.

The presence of Corbicula fluminea in western Lake Erie and the Maumee River necessitates continued stream monitoring and within plant surveillance for these bivalves at the Davis-Besse facility (Docket No. 50-346) and the Enrico Fermi Station (Docket No. 50-341).

Due to the discovery of a specimen of Corbicula fluminea upstream of the Duane Arnold plant site (Docket No. 50-331), continued stream surveillance is recommended to detect the establishment and survival of a population in this reach of the Cedar River.

Although the Grand Gulf facility (Docket Nos. 50-416, 50-417) obtains cooling water from filtered wells, it should be noted that the facility is centrally located in a region of the United States heavily infested by Corbicula fluminea. A danger exists that these bivalves could enter the plant wells or cooling tower basins through inadvertent introduction by workmen or animals carrying larvae or juveniles onto the plant site in clothing or pelage. Continued monitoring of the wells and cooling tower basins is therefore recommended.

The Hope Creek facility (Docket No. 50-354) and Salem 1 and 2 (Docket Nos. 50-272, 50-311), although located on the tidal reaches of the Delaware River, are located near heavy infestations of Corbicula

fluminea upstream near Philadelphia. Further, collections of C. fluminea have been made along the banks of the Delaware River in New Castle County, Delaware across the river from the plant sites. These facilities should exercise caution during years of high river discharge which may allow the temporary establishment of C. fluminea near the plants.

A population of Corbicula fluminea has been detected one mile downstream of the LaCrosse facility (Docket No. 50-409). Frequent examination of the intake structures and cooling tower basins is recommended as well as reproductive periodicity studies of the population near the facility.

Limerick Units 1 and 2 (Docket Nos. 50-352, 50-353) is now located in close proximity to populations of Corbicula fluminea in the Schuylkill River. Further, the Delaware River intake structure in Bucks County, Pennsylvania, is located in the infested portion of the river. Thus, frequent monitoring of intake structures, in-plant water systems, and reproductive periodicity studies are recommended.

Corbicula fluminea populations are located approximately 30 miles downstream from the Monticello facility (Docket No. 50-263). Continual monitoring of the plant's water system and the Minnesota River is therefore recommended.

Palo Verde Units 1, 2, and 3 (Docket Nos. 50-528, 50-529, 50-530) should institute surveillance for Corbicula fluminea infestations. Populations of these bivalves are present throughout the Gila River system (Bequaert and Miller 1973). Further, C. fluminea is able to tolerate life in sewage effluent and has been used as a clarifying agent in tertiary sewage treatment (Haines 1979).

Peach Bottom Units 1 and 2 (Docket Nos. 50-277, 50-278), Susquehanna Units 1 and 2 (Docket Nos. 50-387, 50-388), and Three Mile Island Units 1 and 2 (Docket Nos. 50-289, 50-320) have all stated that the Conowingo Dam on the lower reach of the Susquehanna River will act as a barrier to upstream dispersal by Corbicula fluminea. However, no natural or man-made barriers have as yet effectively inhibited dispersal by C. fluminea. Thus, frequent surveillance of the river and in-plant water systems of these facilities is recommended.

The close proximity of populations of Corbicula fluminea in the Mississippi River to the Prairie Island Units 1 and 2 facility (Docket Nos. 50-282, 50-302) warrants continued monitoring of the river and plant for intrusion by C. fluminea.

The presence of Corbicula fluminea populations in Folsom Lake and the Natimas Reservoir necessitates the continued monitoring of these water bodies and facility water systems for the presence of these bivalves at the Rancho Seco Unit 1 facility (Docket No. 50-312).

Many populations of Corbicula fluminea are found in the Mississippi River in the vicinity of the River Bend Station (Docket Nos. 50-458, 50-459). Thus, the plant should continue to monitor the river and cooling systems for intrusion by these bivalves.

Robinson Unit 2 (Docket No. 50-261) should continue to monitor for the intrusion of Corbicula fluminea since many populations of these bivalves are near the facility. While they have not been found in Robinson Impoundment or Black Creek, the possibility for accidental introduction into freshwater cooling systems does exist.

San Onofre Units 1, 2, and 3 (Docket Nos. 50-206, 50-361, 50-362) is located in close proximity to several populations of Corbicula fluminea, particularly in the San Diego area where the city water works has been infected by these clams. Systems using freshwater should be monitored for intrusion by C. fluminea.

Surry Units 1 and 2 (Docket Nos. 50-280, 50-281) should continue surveillance because of the presence of Corbicula fluminea in the James River and the salinity tolerance of the species.

Washington Nuclear (WNP) 1 and 2 (Docket Nos. 50-460, 50-397) have reported Corbicula fluminea in the Columbia River approximately 5 miles upstream of the plant. Therefore, monitoring of the cooling system and other water systems should be continued to insure early detection of possible infestations by these bivalves. Washington Nuclear 3 (Docket No. 50-508) should also continue monitoring for these bivalves since populations have been detected in Aberdeen Lake and the nearby Willapa River.

Table 4 lists those nuclear facilities that are located within the zoogeographic range of Corbicula fluminea that have a low risk of infestation due to having a salt water cooling system or location of the facility great distances from known populations. Table 5 lists those facilities located wholly outside of the present known zoogeographic distribution of C. fluminea and thus, at present, have little or no chance of being infested by these bivalves.

5.0 ABBREVIATIONS

CD	Cancelled
CHI	Construction Halted Indefinitely
CP	Construction Permit Issued
LPTL	Low Power Test License
NRC	U.S. Nuclear Regulatory Commission
OL	Operating License Issued
SDI	Shut Down Indefinitely
UD/CMS	University of Delaware College of Marine Studies

Table 4. Nuclear facilities located within the zoogeographic range of Corbicula fluminea with low risk of infestation due to either salt water systems or location great distances away from known populations. Facility status derived from Summar Information Report, June 1984. See Section 5.0 for abbreviations.

Facility	Docket No.	Region	Status
Byron 1	50-454	III	CP
Byron 2	50-455	III	CP
Calvert Cliffs 1	50-317	I	OL
Calvert Cliffs 2	50-318	I	OL
Diablo Canyon 1	50-275	V	CP
Diablo Canyon 2	50-323	V	CP
FitzPatrick	50-233	I	OL
Ginna	50-244	I	OL
Humboldt Bay 3	50-133	V	SDI
Indian Point 2	50-247	I	OL
Indian Point 3	50-286	I	OL
Nine Mile Point 1	50-220	I	OL
Oyster Creek 1	50-219	I	OL
Perry 1	50-440	III	CP
Perry 2	50-441	III	CP
St. Lucie 1	50-335	II	OL
St. Lucie 2	50-389	II	OL
Shoreham	50-322	I	CP
Turkey Point 3	50-250	II	OL
Turkey Point 4	50-251	II	OL

Table 5. Nuclear facilities located wholly outside of the present known zoogeographic distribution of Corbicula fluminea. Facility status derived from Summary Information Report, June 1984. See Section 5.0 for abbreviations.

Facility	Docket No.	Region	Status
Big Rock Point 1	50-155	III	OL
Cook 1	50-315	III	OL
Cook 2	50-316	III	OL
Cooper Station	50-298	IV	OL
Ft. Calhoun 1	50-285	IV	OL
Ft. St. Vrain	50-267	IV	OL
Haddam Neck	50-213	I	OL
Kewaunee	50-305	III	OL
Maine Yankee	50-309	I	OL
Midland 1	50-329	III	CP
Midland 2	50-330	III	CP
Millstone 1	50-245	I	OL
Millstone 2	50-336	I	OL
Millstone 3	50-423	I	CP
Palisades	50-255	III	OL
Pilgrim 1	50-293	I	OL
Point Beach 1	50-266	III	OL
Point Beach 2	50-301	III	OL
Seabrook 1	50-443	I	CP
Seabrook 2	50-444	I	CP
Vermont Yankee 1	50-271	I	OL
Wolf Creek 1	50-428	IV	CP
Yankee Rowe 1	50-029	I	OL
Zion 1	50-295	III	OL
Zion 2	50-304	III	OL

6.0 REVIEW OF CORBICULA FLUMINEA DISTRIBUTION BY NRC REGION

Corbicula fluminea is found in the waters of 27 states that have nuclear powered electric generating stations. The results of a review of pertinent literature, zoogeographic records from the University of Delaware College of Marine Studies (UD/CMS) computerized data base, and utility responses to I & E Bulletin 81-03 is presented below by each state of occurrence in the five NRC Regions.

6.1 REGION I

Corbicula fluminea occurs in the waters of four states in Region I: Maryland, New Jersey, New York, and Pennsylvania. Reviews of their distribution in relation to nuclear facilities are presented below.

6.1.1 MARYLAND (Fig. 1)

Stotts et al. (1977) made the first report of Corbicula fluminea from Maryland. Specimens were collected at Susquehanna Flats of the northern reaches of the Chesapeake Bay on silt-sand to hard substrata near Turkey Point and Havre de Grace. Stotts et al. (1977) noted that C. fluminea have been in the bay since 1975. Nichols and Domermuth (1981) noted that populations of C. fluminea are present in the Susquehanna River at Conowingo Dam. These clams may have been the population of origin for those populations at Susquehanna Flats.

Dressler and Cory (1981) reported the discovery of Corbicula fluminea in the Potomac River at the center of Washington, DC (RM 89) to the mouth of Piscataway Creek (RM 84.5) in 1978. They further discussed the fouling of the Potomac Electric Power steam generating station that was so seriously infested that live clams, dead shells, and silt buildup caused operational problems.

Counts (1981b) made the first report of Corbicula fluminea in waters of the Eastern Shore. Specimens were found in the Wicomico River at Salisbury. No fouling problems have been associated with Eastern Shore populations.

An examination of the UD/CMS data base indicates the following Maryland water bodies support populations of Corbicula fluminea: The upper reaches of Chesapeake Bay, Nassawango Creek, Potomac River, Susquehanna River, and Wicomico River.

The Calvert Cliffs plant is located along the more saline reaches of Chesapeake Bay. In the response to I & E Bulletin 81-03, no problems with Corbicula fluminea at the facility were reported (Lundvall 1981).

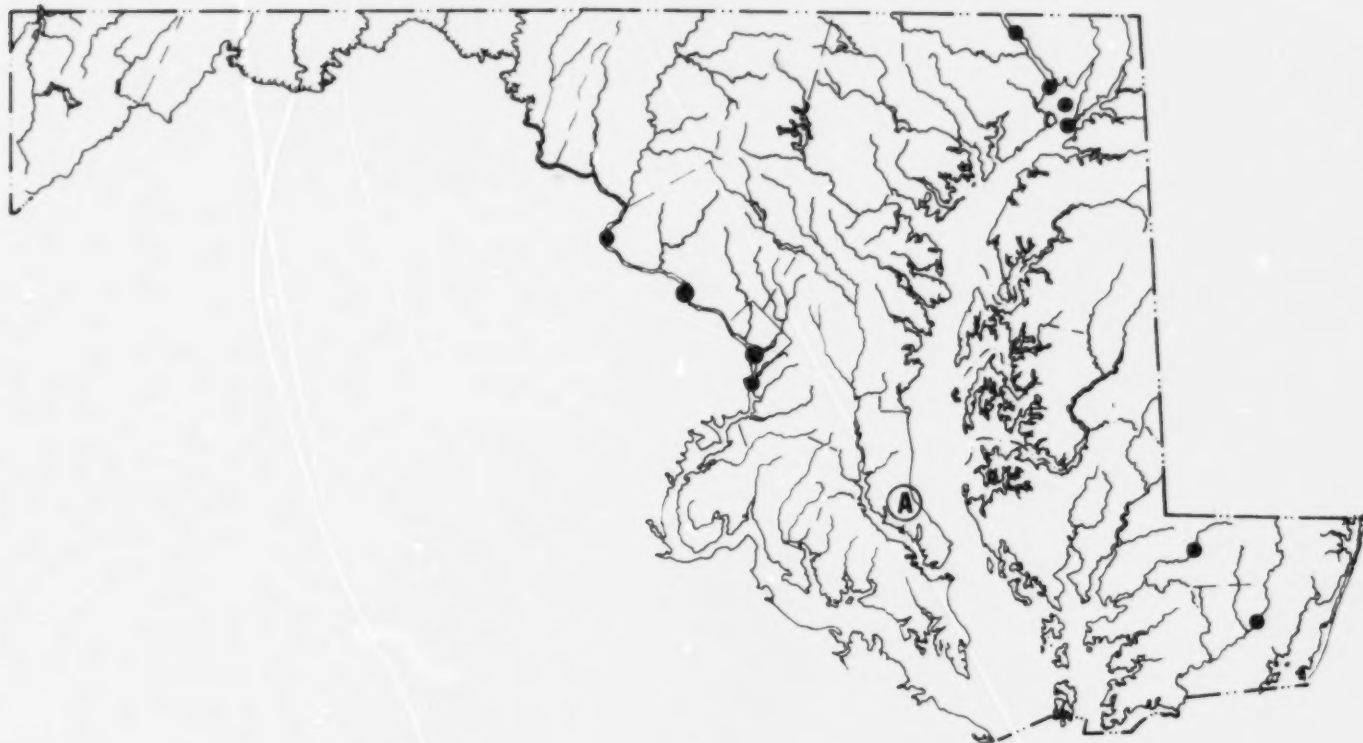


Figure 1. Zoogeographic distribution of Corbicula fluminea in Maryland.
A = Calvert Cliffs (OL). Scale bar = 50 km.

6.1.2 NEW JERSEY (Fig. 2)

The first report of Corbicula fluminea in New Jersey was made by Fuller and Powell (1973) who recorded its presence in the Delaware River between Trenton and Philadelphia. Bivalves seemed to prefer muddy and fine gravel substrata.

Crumb (1977) reported on the colonization of the Delaware River by Corbicula fluminea and noted the extension of its range between Trenton and Burlington. Crumb hypothesized that C. fluminea invaded the Delaware River sometime during, or before 1971 and noted that it was usually found in sand or coarse sediments, as reported by Fuller and Powell (1973). He also found that the bivalve Sphaerium transversum was common in the Delaware River until the expansion of the population of C. fluminea. Corbicula fluminea, with Limnodrilus spp., Procladius cruciformis, and Pelosclex ferox dominated the benthic community at his collection sites.

Trama (1982) reported a population of Corbicula fluminea in the Raritan River. Populations were successful in both the tidal and non-tidal portions of the river as well as in the North and South Branches of the river.

An examination of the UD/CMS data base reveals the presence of Corbicula fluminea in the following New Jersey streams: Delaware River and Raritan River.

No nuclear facility in New Jersey reported fouling problems with Corbicula fluminea in their response to I & E Bulletin 81-03 (Rains et al. 1984). Salem 1 and 2 (Docket Nos. 50-272, 50-311) noted that the salinity range (6-8 ppt mean; 1-18 ppt range) is too high to allow successful colonization of the Delaware River at Artificial Island. However, Mouthon (1981) found populations of C. fluminea in France and Portugal living in waters of much higher salinity. Recent work by King et al. (1985) reports successful reproduction and development of C. fluminea collected in Delaware in salinities between 0 and 8 ppt. Further, specimens of C. fluminea were collected from the Delaware side of the Delaware River in New Castle County in July 1981 (TCU 5835). Therefore, colonization of the waters at Artificial Island is within the realm of possibility.

6.1.3 NEW YORK (Fig. 3)

The only report of Corbicula fluminea in New York is that of Raeihle (1983). A population was discovered in Massapequa Lake, eastern Nassau County, Long Island in November 1977. Subsequent examinations of this population conducted every year up to 1983, revealed the population was stable. This is the only record for the state in the UD/CMS data base.

The rest of New York state is outside of the known zoogeographic limits of Corbicula fluminea and the species does not presently threaten nuclear facilities. The nuclear power station located on Long Island, Shoreham (Docket No. 50-322), has a salt water cooling system and has reported no incidence of fouling by C. fluminea (Pollock 1981, Rains et al. 1984).

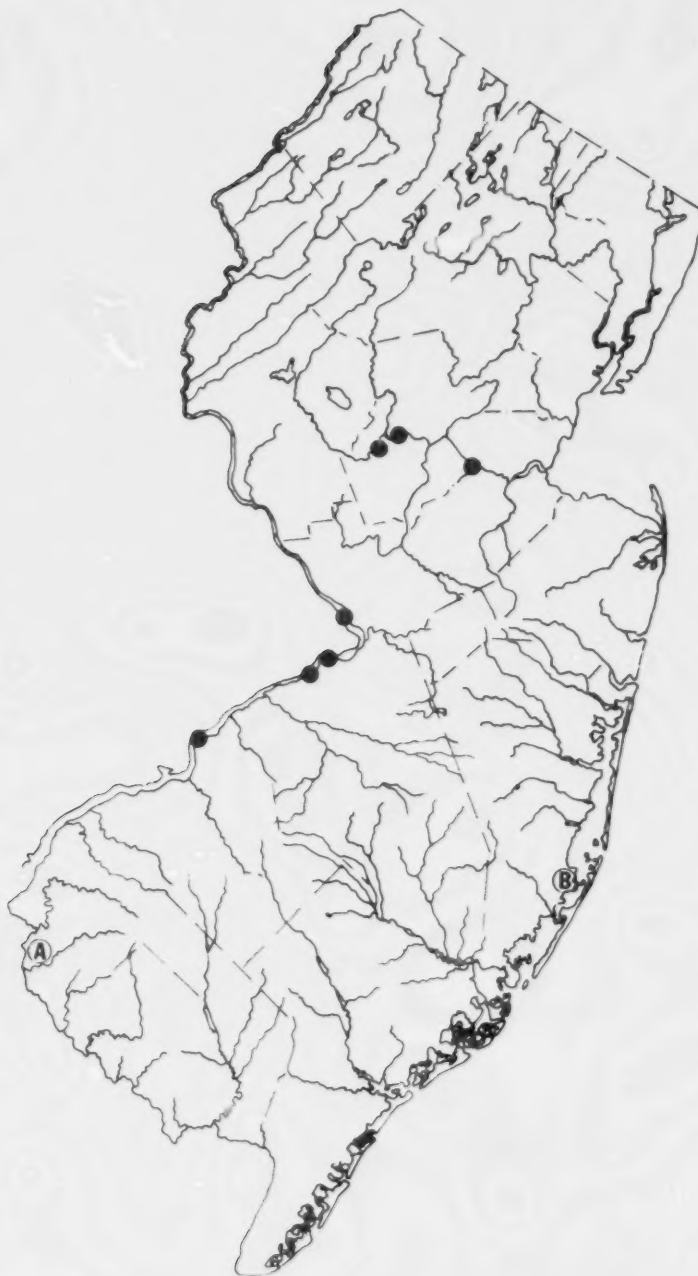


Figure 2. Zoogeographic distribution of *Corbicula fluminea* in New Jersey. A = Salem (OL), Hope Creek (CP); B = Forked River (CD), Oyster Creek (OL). Scale bar = 50 km.



Figure 3. Zoogeographic distribution of *Corbicula fluminea* in New York.
 A = Ginna (OL); B = FitzPatrick (OL), Nine Mile Point (OL, CP);
 C = Indian Point (OL); D = Shoreham (CP); E - Jamesport (CD).
 Scale Bar = 50 km.

6.1.4 PENNSYLVANIA (Fig. 4)

Corbicula fluminea has been reported in the literature only from the Ohio River at Pittsburgh (Taylor 1980). However, the species is known to inhabit the Monongahela River in Fayette County.

Although the species is found in the Susquehanna River below Conowingo Dam, Maryland, it has not yet moved upstream into Pennsylvania (Nichols and Domermuth 1981). No other records, other than those for the Delaware River, which is a part of New Jersey, have been reported for the state.

The Annual Environmental Reports for Beaver Valley 1 (Docket No. 50-334) (Duquesne Light Co. 1979, 1980, 1981, 1982, 1983) reported that Corbicula fluminea was collected from 1974 through 1978 and from 1981 through 1983. No specimens were found for 1979 or 1980. The response by Beaver Valley 1 to I & E Bulletin 81-03 noted that the shells of C. fluminea have been found in the Main Condenser Inlet Water Boxes and Chilled Water Condensers. They also reported that approximately 30 shells of 0.5 inch diameter were removed from the Reactor Plant Component Water Heat Exchangers (Carey 1981).

The reports from the Monongahela and Ohio Rivers are the only records for the state in the UD/CMS data base.

Nuclear facilities located on the Susquehanna River (Peach Bottom [Docket Nos. 50-277, 50-278], Three Mile Island [Docket Nos. 50-389, 50-320], and Susquehanna [Docket Nos. 50-387, 50-388]) have reported no evidence of Corbicula fluminea at or near their facilities (Gallagher, 1981, Hovey 1981, Hukill 1981, Curtis 1981). The response to I & E Bulletin 81-03 by the Peach Bottom facility stated that "They [C. fluminea] are kept out of the Conowingo Pond by Donowingo Dam" and that "no surveillance [is] needed" (Gallagher 1981). The other two facilities have also stated that C. fluminea is kept out of the upper Susquehanna River by Conowingo Dam. In view of the probable dispersal of these bivalves by man (Counts 1983) and larval transport on the feathers of migratory waterfowl (McMahon 1983), Conowingo Dam offers no significant barrier to the upstream dispersal of C. fluminea in the Susquehanna River. Therefore, it is recommended that the three nuclear facilities above the dam institute surveillance programs.

6.2 REGION II

Corbicula fluminea occurs in the waters of 8 states of Region II that have nuclear powered electric generating plants. Region II states lie within the part of the United States where C. fluminea populations are densest.

6.2.1 ALABAMA (Fig. 5)

Corbicula fluminea was first reported in Alabama in the Mobile River in 1962 (Hubricht 1963). In the fall of 1964 it was found in the Alabama River (Hubricht 1965) and in the following year it appeared in the Cahaba and Tombigbee rivers and in Sucarnocree Creek (Hubricht 1966).

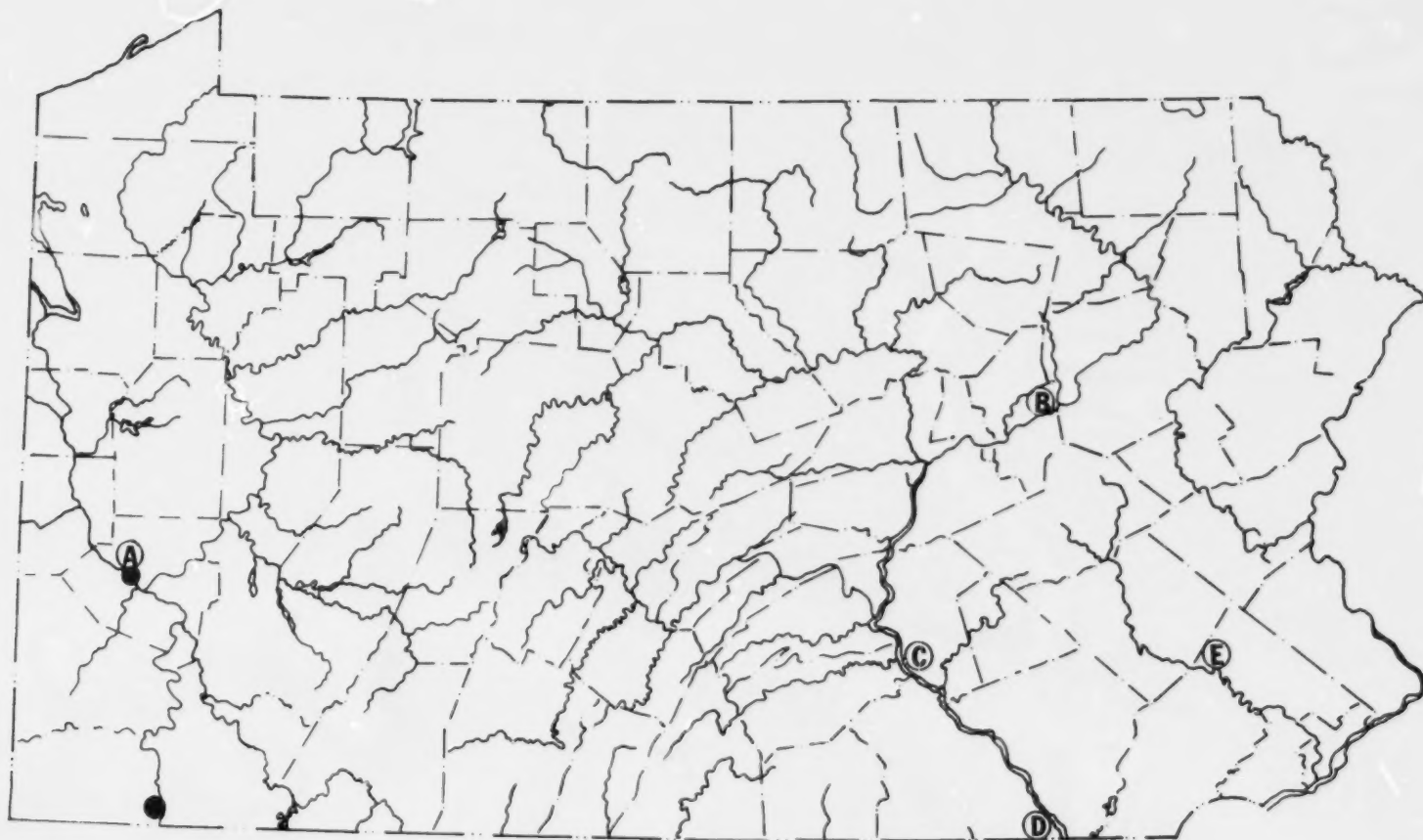


Figure 4. Zoogeographic distribution of *Corbicula fluminea* in Pennsylvania. A = Beaver Valley (OL, CP); B = Susquehanna (OL, CP); C = Three Mile Island (OL, SDI); D = Peach Bottom (OL); E = Limerick (OL). Scale bar = 50 km.

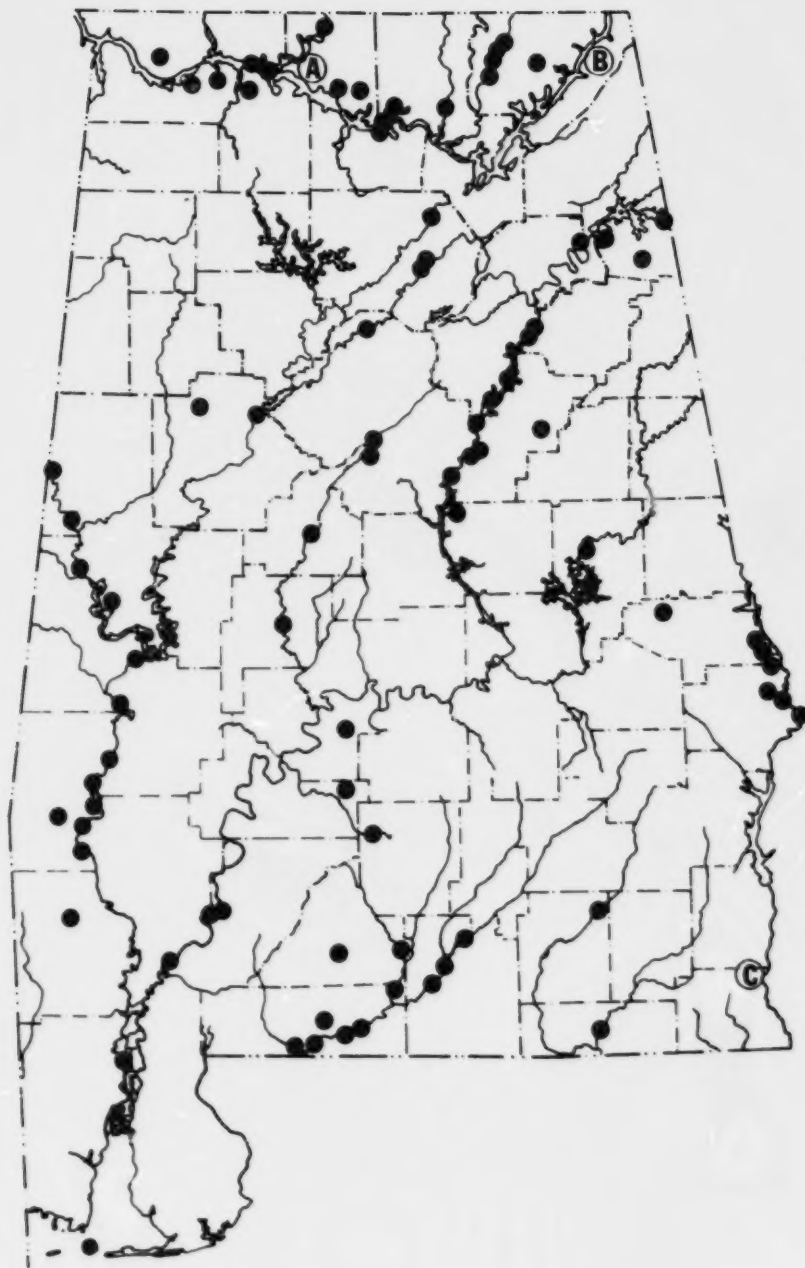


Figure 5. Zoogeographic distribution of *Corbicula fluminea* in Alabama. A = Browns Ferry (OL); B = Bellefonte (CP); C = Farley (OL). Scale bar = 50 km.

Shealy (1966) reported predation of Corbicula fluminea by the Alabama map turtle, Graptemys pulchra Baru, in the Conecuh River of the Escambia River system. This predation did not significantly reduce the C. fluminea population in that stream.

Jenkinson (1979) reported the occurrence of Corbicula fluminea in the main streams and tributaries of the Chattahoochee and Tallapoosa River in east-central Alabama in 1973. He noted that the population in Saugahatchie Creek, a tributary of the Tallapoosa River, is apparently thriving in waters receiving effluents from a textile mill, a sewage treatment plant, and runoff from the experimental ponds of Auburn University. C. fluminea was usually found in clay and sand substrata in these streams.

A review of the UD/CMS data base reveals the presence of Corbicula fluminea in the following Alabama water bodies: Alabama River, Big Cedar Creek, Big Nance Creek, Black Warrior River, Buck Creek, Burnt Corn Creek, the Cahaba River, Cedar Creek, Chattahoochee River, Choctawhatchee River, Conecuh River, Coosa River, Cypress Creek, pools on Dauphin Island, Drivers Branch, Elk River, Escambia River, Flint River, Gantt Lake, Indian Creek, Limestone Creek, Little Cahaba River, Little Cypress Creek, Little Uchee Creek, Locust Fork, Mobile River, Mud Creek, Mulberry Fork of the Black Warrior River, Murder Creek, Neely Henry Lake, North River, Okatuppa Creek, Paint Rock River, Pea River, Peckerwood Creek, Piney Creek, Santa Bouge Creek, Sauganatchee Creek, Second Creek, Sucarnochee Creek, Sepulga River, Tallapoosa River, Tennessee River, Terrapin Creek, Tombigbee River, Town Creek, Tubbs Creek, and Uchee Creek.

The response to I & E Bulletin 81-03 by the Browns Ferry Nuclear Plant (Docket Nos. 50-259, 50-260, 50-296), located on the Tennessee River, indicated fouling problems caused by Corbicula fluminea were first detected in 1974 (Mills 1981a). Condenser efficiency for Units 1 and 2 was lost and visual inspection revealed heavy infestation by C. fluminea in the tube sheets of several water boxes. In December 1974, a leaking heat exchanger on the 1B recirculating pump MG set drive motor was dismantled and a partial obstruction by clams was found. Several hundred pounds of C. fluminea were removed when all water boxes and intake conduits were drained. Further, heat exchangers in the emergency cooling water system, the raw-cooling water system, and the high pressure fire protection system had some degree of fouling by C. fluminea. Scuba divers, investigating the intake structure forebay found a large population of C. fluminea at all stages of development.

Farley Nuclear Plant (Docket Nos. 50-348, 50-364), located on the Chattahoochee River, reported the presence of Corbicula fluminea in the cooling tower basins for Unit 1 in 1978 (Clayton 1981). These bivalves originated in the service water pond that hold makeup water for the circulating water system. However, no fouling or plugging of heat exchangers was demonstrated. During the routine refueling outage of 1981 for Unit 2, no fouling by C. fluminea was found. A benthic survey of the Chattahoochee River conducted in April 1981 revealed the presence of

C. fluminea at river mile 14 and river mile 48 (approximately 4 miles upstream of the intake structures). C. fluminea was collected in all areas sampled in the cooling pond.

No instances of fouling by Corbicula fluminea were reported by the Bellefonte Nuclear Plant (Docket Nos. 50-438, 50-439), under construction on the Tennessee River (Mills 1981b).

6.2.2 FLORIDA (Fig. 6)

The earliest reports of Corbicula fluminea in Florida are those of Heard (1964, 1966). Heard (1964) reported C. fluminea in the Apalachicola, Chipola, and Withlacoochee Rivers. He later hypothesized that upon the completion of the Cross-Florida Barge Canal, C. fluminea could move across the state to inhabit the St. Johns River system (Heard 1966). This hypothesis has since been proved correct. Gifford (1974) found C. fluminea in the Cross-Florida Barge Canal and reported that these bivalves reached a biomass of 500 g live tissue/per square meter.

Schneider (1967) found Corbicula fluminea in the Escambia River during a survey by the Florida State Board of Health in 1960. He believed these bivalves invaded the Escambia River sometime in 1959. Corbicula fluminea was found in 1961 in the Apalachicola River, which receives the Chattahoochee River. By 1967, C. fluminea ranged from the Escambia River near Century to the Withlacoochee near Inglis.

Clench (1970) found that Corbicula fluminea's range extended into the Caloosahatchee River - Lake Okeechobee system. He hypothesized that their presence in the system may lead to the spread of C. fluminea throughout all of southern Florida.

Deaton (1981) found Corbicula fluminea in the Oklocknee River in waters of about 0.1 ppt salinity and in association with the native unionid bivalve Lamellis claibornensis.

A review of the UD/CMS data base revealed the presence of Corbicula fluminea in the following waters of Florida: Apalachicola River, Aucilla River, Caloosahatchee River, Chipola River, Choctawhatchee River, Cypress Creek Canal, Escambia River, Ft. Lauderdale Canal, Grassy Lake, Holmes Creek, Ichetucknee River, Indian Prairie Canal, Kissimmee River, Lake Buena Vista, Lake Hippochee, Lake Jackson, Lake Lucy, Lake Okeechobee, Lake Oklawaha, Lake Palatalakha, Lake Talquin, Lake Tsala, Main Canal, Mayakka River, Middle River Canal, Mosquito Creek, North Mosquito Creek, Oklocknee River, Oklawaha River, Rocky Creek, St. Joseph Bay, St. Johns River, Santa Fe River, Sky Lake, Spring Creek, Steinhatchee River, Suwannee River, Waccasassa River, Wekiva River, Withlacoochee River, and Yellow River.

Crystal River Nuclear Plant (Docket No. 50-302), St. Lucie Nuclear Plant (Docket Nos. 50-335, 50-389), and Turkey Point Nuclear Plant (Docket Nos. 50-250, 50-251) reported no incidence of fouling by Corbicula fluminea in their responses to I & E Bulletin 81-03 (Baynard 1981, Uhrig 1981a, b). All of these plants are cooled by sea water.

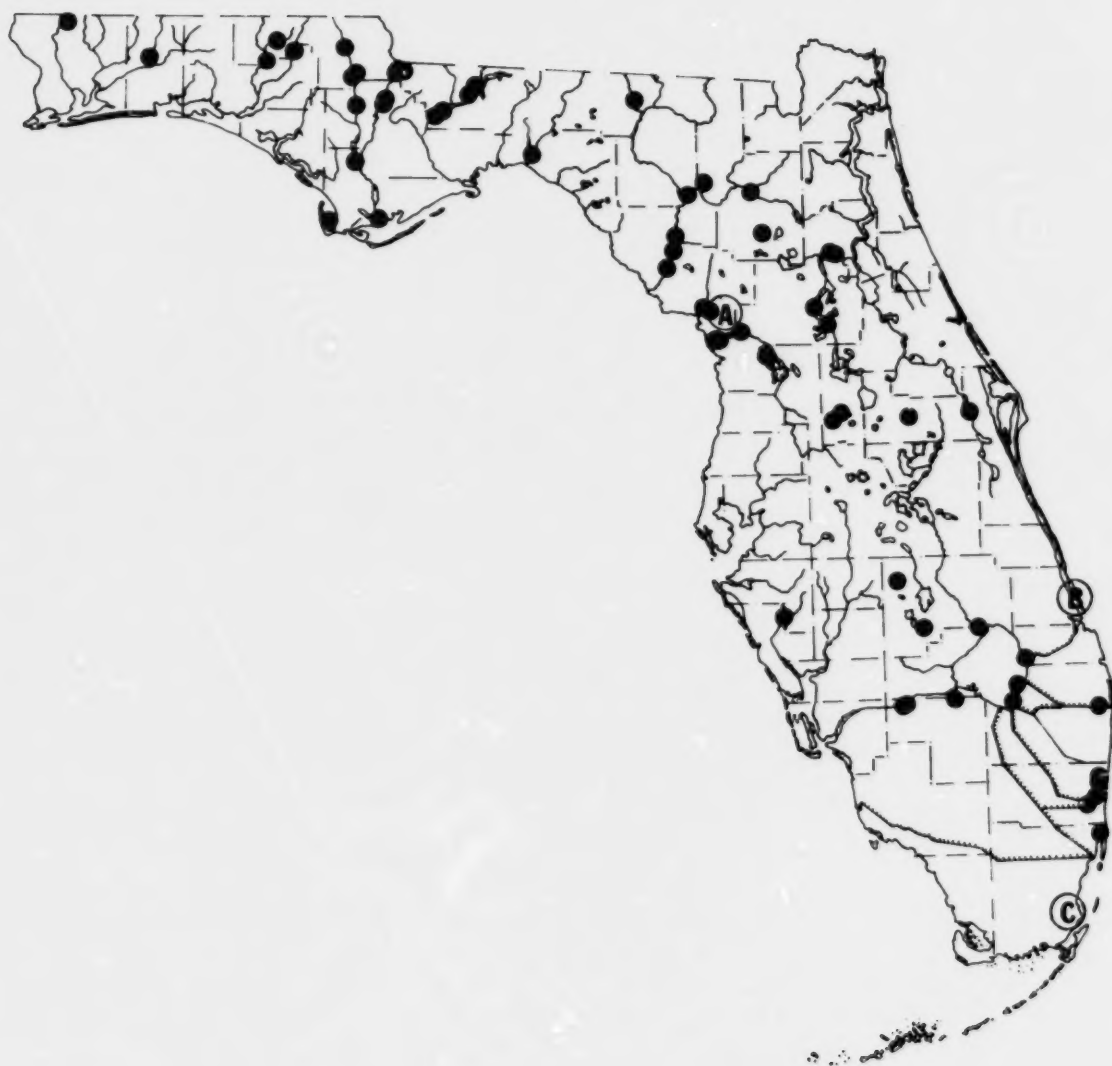


Figure 6. Zoogeographic distribution of *Corbicula fluminea* in Florida. A = Crystal River (OL), B = St. Lucie (OL), C = Turkey Point (OL). Scale bar = 50 km.

6.2.3 GEORGIA (Fig. 7)

The first specimens of Corbicula fluminea reported in Georgia were collected from the Altamaha River in 1971 near river mile 116 (Sickel 1973). Later, in 1971, populations were also found in the Ocmulgee and Flint Rivers (Sickel 1973). The Flint River and the Altamaha River populations were found in association with Lampsilis anodontoides floridensis (Lea), L. unio (Simpson), and Quincuncina infurcata (Conrad) in coarse sand substrata (Sickel 1973).

Sickel (1976) reported the Altamaha River population increased to a density of more than 2500/m² between 1971 and 1974. However, Gardner et al. (1976) reported densities of 10,000/m² in 1974 in some localities in the Altamaha River. These population increases were accompanied by a decline in populations of unionid bivalves (Gardner et al. 1976).

Fuller and Powell (1973) reported Corbicula fluminea in the Savannah River in 1972. Fuller and Richardson (1977) noted that the success of C. fluminea in that river and reported that these bivalves actively uproot unionid bivalves.

Walker (1982) reported mass mortalities of Corbicula fluminea in the Towaliga River, a tributary of the Ocmulgee River in 1981. He believed a similar mortality occurred in the same stream in 1980. However, no causative factor was identified for these mass mortalities.

Records for Corbicula fluminea in the following Georgia waters are found in the UD/CMS data base: Altamaha River, Chattahoochee River, Chickamauga Creek, Chickasawhatchee River, Coahulla Creek, Consauga River, Flint River, Lake Allatoona, Little Ocmulgee River, Ogeechee River, Ohoopie River, Oostanula River, Potatoe Creek, Pound Creek, Savannah River, Towaliga River, and Withlacoochee River.

Although Corbicula fluminea has been found in the Altamaha River, the response to I & E Bulletin 81-03 for Hatch Nuclear Plant (Docket Nos. 50-321, 50-366), which draws its service and circulating water from this river, indicated no instances of within plant fouling has occurred.

The response to I & E Bulletin 81-03 by Plant Vogtle (Docket Nos. 50-424, 50-425), under construction on the Savannah River, near the Savannah River Plant, South Carolina, reported substantial populations in the river above and below the plant site (Dutton 1981). In view of the continual, extensive fouling problems experienced at the Savannah River Plant (Harvey 1981), Plant Vogtle will have to exercise extreme care in the development and execution of its surveillance program.

6.2.4 MISSISSIPPI (Fig. 8)

Heard (1966) first discovered Corbicula fluminea in Mississippi in the Yazoo River at Vicksburg in 1963. He also reported on populations in the Coldwater and Leaf Rivers. Grantham (1967) reported C. fluminea in the Chickawhaw, Pascagoula, and Pearl Rivers. Grantham (1969) later reported C. fluminea in the Big Black, Deer, Leaf, Tennessee, and Tombigbee Rivers.

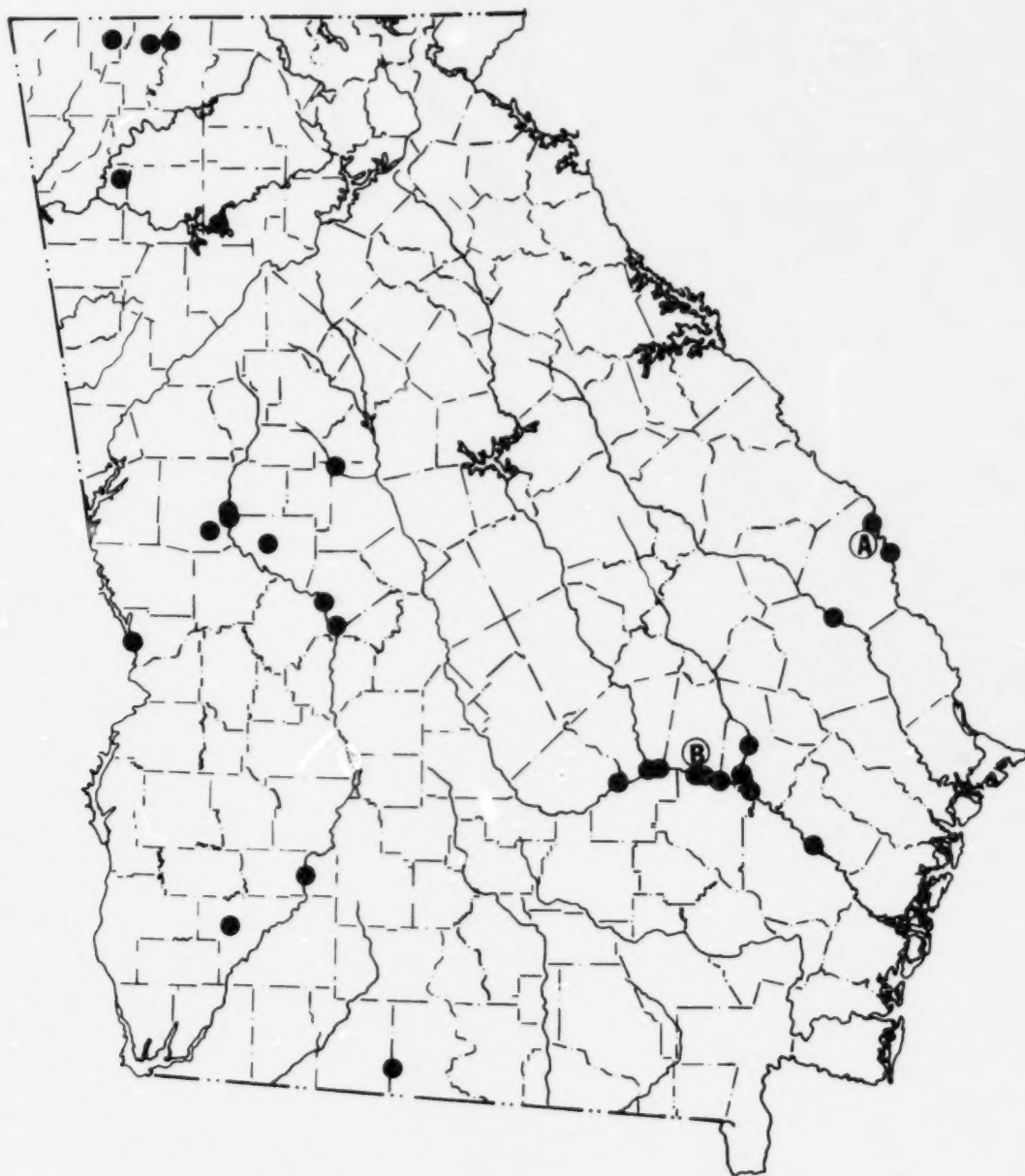


Figure 7. Zoogeographic distribution of *Corbicula fluminea* in Georgia.
A = Vogtle (CP); B = Hatch (OL, CP). Scale bar = 50 km.

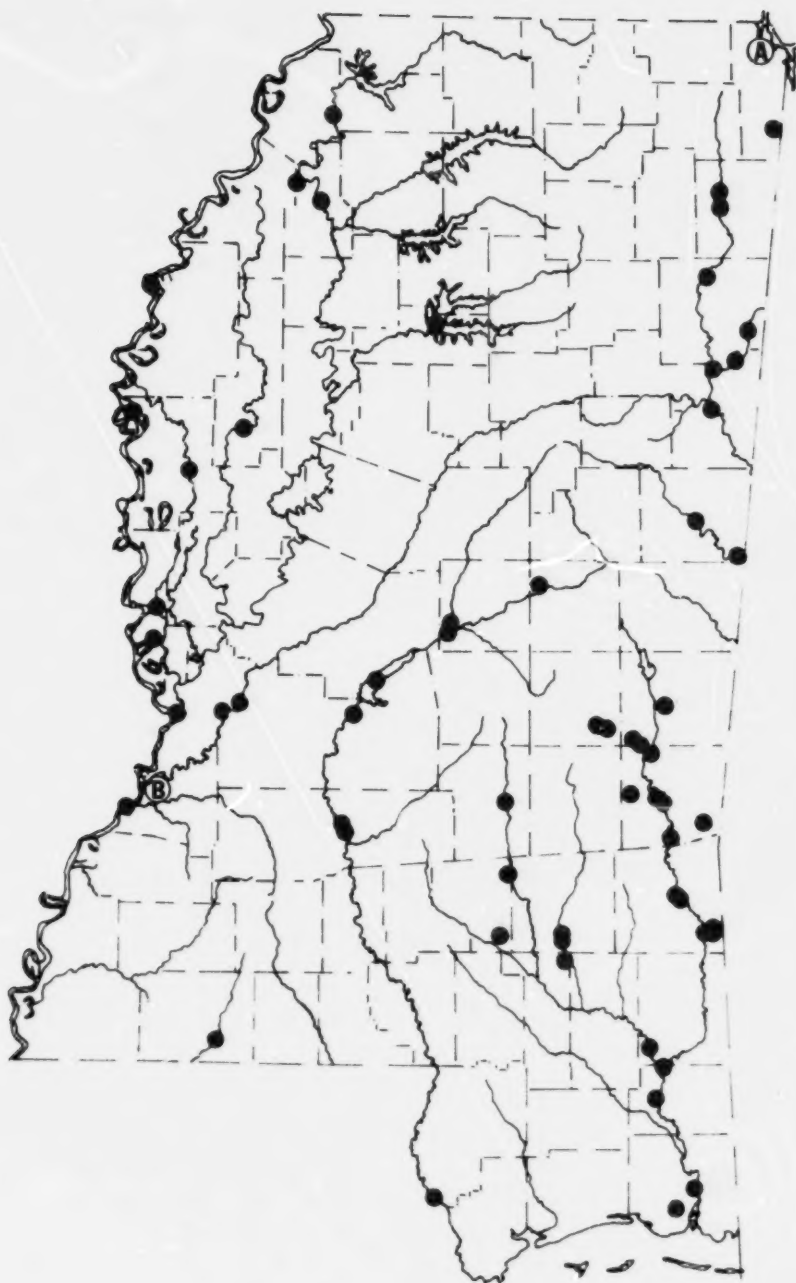


Figure 8. Zoogeographic distribution of *Corbicula fluminea* in Mississippi. A = Yellow Creek (CD); B = Grand Gulf (LPTL, OL). Scale bar = 50 km.

Cooper and Johnson (1980) reported Corbicula fluminea in the Grenada Reservoir of the Yalobusha River during studies conducted there between 1973 and 1976. Leard et al. (1980) collected C. fluminea from the Big Black, Chickasawhay, Chucky, Coldwater, Leaf, and Pearl Rivers and from Steel Bayou and Black Creek.

King and Miller (1982) reported Corbicula fluminea to be the most abundant bivalve species in the Tombigbee River near Columbus. Hartfield and Cooper (1982) reported C. fluminea to be absent in the southern part of the state between, but not including, the Pascagoula and Pearl Rivers and streams that drain into the lower Mississippi River; Bayou Pierre, Buffalo Bayou, and the Homochitto River.

Records for Corbicula fluminea in the following Mississippi waters are found in the UD/CMS data base: Allan Branch, Amite River, Bayou Pierre, Bear Creek, Big Black Creek, Big Black River, Bogue Chitto River, Chugatonchee Creek, Bouge Homa Lake, Bouge Phalia River, Buckatunna Creek, Bull Mountain Creek, Buttahatchie River, Chickasawhat River, Chunky River, Coldwater River, Lake Bolivar, Lake Washington, Leaf River, Lost Rabbit Reservoir, Mississippi River, Moss Creek, Noxubee River, Okatibee Creek, Okatoma Creek, Pascagoula River, Pearl River, Pelahatchie Creek Reservoir, Sjubuta River, Souinlovey Creek, Steel Bayou, Strong River, Tallahala Creek, Tangipahou Creek, Tombigbee River, Woodward Creek, Yalobusha River, Yazoo River, and Yockanookay River.

Grand Gulf Nuclear Station (Docket Nos. 50-416, 50-417), in its response to I & E Bulletin 81-03, reported the detection of Corbicula fluminea in the Mississippi River during the preconstruction phases in 1972 and 1973 (McGaughy 1981). Population densities were small and later surveys by the U.S. Army Corps of Engineers found smaller densities. No fouling by C. fluminea has been detected at this facility.

6.2.5 NORTH CAROLINA (Fig. 9)

The earliest report of Corbicula fluminea in North Carolina was made by Fox (1971) who reported specimens taken at the fossil-fueled Allan Steam Station at Lake Wylie of the Catawba River system in 1970. Fuller and Imlay (1976) later reported C. fluminea in Lake Waccamaw, and speculated that the population became established only where the habitat was severely disturbed by man.

Lauritsen and Mozley (1983) described the infestation of the Chowan River and noted that the infestation of the upper reaches of the river and its tributaries was completed sometime between 1974 and 1978. Population densities were stable at 200 clams/m and they noted that C. fluminea is able to rapidly recycle nutrients important to phytoplankton growth (NH₄⁺, PO₄³⁻) such that where clams are present, their excretion rates for these nutrients are significantly higher than sediment flux rates.

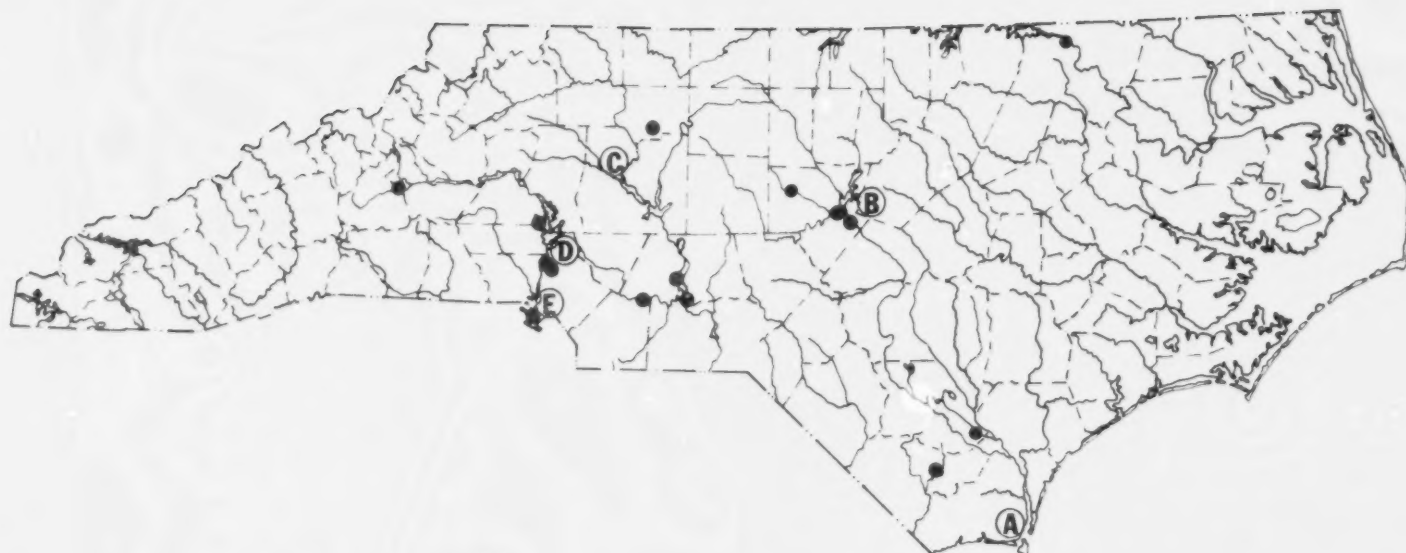


Figure 9. Zoogeographic distribution of *Corbicula fluminea* in North Carolina. A = Brunswick (OL); B = Harris (CP); C = Perkins (CD); D = McGuire (OL). Scale bar = 50 km.

Hall (1984) reported on the Corbicula fluminea population in Lake Norman (the location of McGuire Nuclear Power Station). He noted that the species was first found in the lake in 1972. The increase of biomass of C. fluminea in Lake Norman has been approximately sixty-fold, increasing from 0.1% in January of 1974, to 85% in October 1978, of the total benthic biomass collected in the sublittoral zone of the lake.

Records for North Carolina waters in the UD/CMS data base are as follows: Buckhorn Creek, Cape Fear River, Catawba River, Chowan River, Eden River, Lake James, Lake Norman, Lake Wylie, Lake Waccamaw, Little River, Long Mountain Island Lake, Neuse River, Richardson Creek, Roanoke River, Rocky River, Tar River, Uwharrie River, and Waccamaw River.

The Harris Nuclear Power Plant (Docket Nos. 50-400, 50-401) response to I & E Bulletin 81-03 indicated the presence of Corbicula fluminea in the Cape Fear River near the plant site since about 1974. Further, C. fluminea has invaded Buckhorn Creek, the major tributary of Shearon Harris Reservoir, the makeup water source for the plant (Utley 1981). No fouling has been found at the Harris Station, which is under construction.

McGuire Nuclear Station (Docket Nos. 50-369, 50-370), in its response to I & E Bulletin 81-03, noted Corbicula fluminea was first detected during pre-operational tests of the fire protection system in August 1978. As of May 1981, clams were found only in the fire protection system and in the standby nuclear service water pond (first detected in 1979 and again in 1981) (Parker 1981b).

The response of Brunswick Steam Electric Plant (Docket Nos. 50-324, 50-325) to I & E Bulletin 81-03 indicated that Corbicula fluminea was not found in the tidal portion of the Cape Fear River (Furr 1981). This absence was attributed to high salinity of the water.

6.2.6 SOUTH CAROLINA (Fig. 10)

The first published report of Corbicula fluminea in South Carolina is that of Fuller and Powell (1973). They found "gapers" and living specimens in the Pee Dee River on hard clay and sand substrata in 1972. They further reported populations found in 1973 in the Savannah River near Augusta, Georgia. Fuller later reported C. fluminea to be abundant in the Cooper River (Fuller, 1974) and in the Santee-Cooper systems (Fuller, 1976).

Fuller and Imlay (1976) found numerous living and dead specimens of Corbicula fluminea below the confluence of the Waccamaw River with the Intracoastal Waterway. Fuller (1978a) later noted the establishment of a population in the Intracoastal Waterway in Georgetown County.

The infestation of the Savannah River Plant by Corbicula fluminea has received wide attention in the literature. Tilly et al. (1978) noted severe yearly infestations at the plant and reported on irradiation experiments using gamma ray irradiation. Boozer and Mirkes (1979) discussed the association of C. fluminea with Musculum partumenum in



Figure 10. Zoogeographic distribution of *Corbicula fluminea* in South Carolina. A = Cherokee (CD); B = Summer (OL); C = Robinson (OL); D = Oconee (OL); E = Catawba (OL, CP). Scale bar = 50 km.

the sedimentation basin at the plant. Britton and Fuller (1979) reported that C. fluminea was found at 7 localities in the Savannah River along the perimeter of the plant. They also collected C. fluminea in the lower reach of Upper Three Runs. They noted that C. fluminea was abundant at every locality sampled in the river and densities were reported to be in excess of 2000 living clams/m². They also found C. fluminea in Beaver Dam Creek, located upstream of Savannah River Plant and commented on the limited access of C. fluminea to most Savannah River Plant streams.

Harvey (1981) reported on the recolonization of the water cooling systems of the P-, C-, and K-area reactors and noted that the pumps, reactor basins, pump wells, and emergency cooling systems must be cleaned every 10 months to keep them free of these bivalves.

South Carolina stream records for Corbicula fluminea in the UD/CMS data base are: Beaver Dam Creek, Cooper River, Edisto River, Hartwell Reservoir, Intracoastal Waterway, Lake Keowee, Lake Marion, Little Pee Dee River, Salkahatchie River, Saluda River, Savannah River, South Edisto River, Upper Three Runs, and Waccamaw River.

The response to I & E Bulletin 81-03 submitted by the Catawba Nuclear Station (Docket Nos. 50-413, 50-414) reported the presence of Corbicula fluminea in Lake Wylie since the mid-1960's and noted the fouling of a fossil fueled plant in 1970. Minor fouling (none serious enough to cause operational problems), was found in a conventional low pressure service water system supply header (1 0.5 in. shell) and in the fire protection system (3 0.25 in. shells). Some small shells and shell fragments were found in a few deluge nozzels of the fire protection system (Parker 1981a).

The response to I & E Bulletin 81-03 by Oconee Nuclear Station (Docket Nos. 50-269, 50-270, 50-287) (Parker 1981) reported that Corbicula fluminea were detected in Lake Keowee for the first time in September 1980 in the plants intake canal. A small number of shells were also found in the Amertap ball collection baskets for Unit 1 in December 1980. An inspection of the circulating cooling water pump wells in May 1981 demonstrated the presence of the clams at the intake structure. Clams were also discovered in the fire protection system at Keowee Hydro Station during a hydrant test on 26 May 1981.

Summer Nuclear Station (Docket No. 50-395), in its response to I & E Bulletin 81-03, reported the presence of Corbicula fluminea in Monticello Reservoir, Parr Reservoir, and Neal Shoals in 1979 and 1980. C. fluminea did not appear in Neal Shoals until 1979. However, no incidence of fouling was reported at the plant (Nichols 1981).

Corbicula fluminea was not found at Robinson Steam Electric Plant (Docket No. 50-261) (Furr 1981). No clams could be found in either Robinson Impoundment or Black Creek. This absence was attributed to the naturally occurring low pH of these "black waters".

6.2.7 TENNESSEE (Fig. 11)

The first account of Corbicula fluminea in Tennessee appears in Sinclair and Isom (1961) and described the infestation below Pickwick Dam of the Tennessee River in 1959. By 1961, C. fluminea had also invaded the Cumberland River of Tennessee (Sinclair and Isom 1961). By 1962, C. fluminea had infested the Johnsonville Steam Plant on Kentucky reservoir and public and industrial water supplies as well as a sand and gravel quarry at Chattanooga (Sinclair and Isom 1963). Introduction of C. fluminea into the Tennessee River occurred sometime after 1958, and a survey of the mussels of Kentucky Reservoir by Bates (1962a) did not reveal their presence in 1958.

Sinclair and Isom (1964) discussed infestations of the sand and gravel industries of Tennessee and Cumberland Rivers and described the deleterious effects of Corbicula fluminea in freshly poured concrete.

Isom and Yockley (1968) found Corbicula fluminea at 10 stations in the Duck River between river miles 71 and 242.5 in 1965. Clench and Stansbery (1969) later reported the infestation of the Nolichucky River southwest of Warrensburg and noted that these populations were found living in beds of angular limestone, loose limestone rocks, gravel, sand, and sandy mud substrata.

Isom (1971) reported Corbicula fluminea from the Fort London Reservoir of the Tennessee River in 1970, and later (Isom 1972) reported an infestation at the Nickajack Dam site first noted in 1965 before completion of the dam.

Isom et al. (1973) found Corbicula fluminea in the Elk River Basin during studies made in 1965 to 1967. Van der Schalie (1973) further noted the presence of C. fluminea in the Duck and Buffalo Rivers, tributaries of the Tennessee River and noted that they are commonly eaten by mink and muskrat, thus replacing the once numerous unionid bivalves as a food source for these mammals.

Goss and Cain (1977) discussed the history of biofouling by Corbicula fluminea at the Tennessee Valley Authority's Johnsonville Steam Plant as well as the fouling of Brown's Ferry Nuclear Plant in late 1974. They also discussed various techniques used to control these bivalves.

Eagleson and Morgan (1977) reported the growth rates of populations of Corbicula fluminea in the Clinch River and two small tributaries, Grassy Creek and Bear Creek, near Oak Ridge in 1975 - 1976.

Ahlstedt (1983) found Corbicula fluminea in 59 of 108 collection localities in the Elk River during the period June-September 1980. At some localities, C. fluminea was the only bivalve found.

The UD/CMS data base contains records for the following Tennessee waters: Barren Fork River, Big Bigby Creek, Big Hickory Creek, Big Rock Creek, Big Swan Creek, Buffalo River, Clinch River, Collins River,

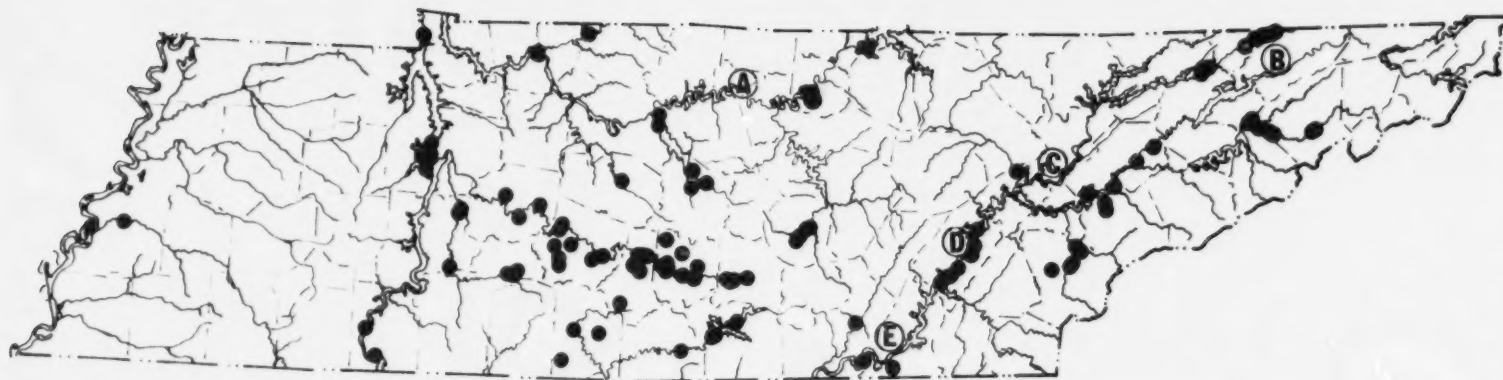


Figure 11. Zoogeographic distribution of Corbicula fluminea in Tennessee. A = Hartsville (CD); B = Phipps Bend (CD); C = Clinch River (CD); D = Watts Bar (CP); E = Sequoyah (OL). Scale bar = 50 km.

Cumberland River, Duke River, East Rock Creek, Elk River, Emory River, Fall Creek, Flat Creek, Fountain Creek, Garrison River, Greenlick Creek, Harpeth River, Hatchie River, Holston River, Lick Creek, Sequatchie River, Shoal Creek, Sinking Creek, South Chickamauga Creek, Stones River, Sugar Creek, Tellico River, Tennessee River, and Weakly Creek.

Corbicula fluminea was reported from waters adjacent to the sites of Hartsville (Docket Nos. 50-518, 50-519, 50-520, 50-521) and Phipps Bend (Docket Nos. 50-553, 50-554) nuclear power stations in April 1977 and June 1980, respectively (Mills 1981a). Construction of both facilities is postponed.

The prominence of Corbicula fluminea in the vicinity of Watts Bar Nuclear Plant (Docket Nos. 50-390, 50-391) has been established since 1971 (Mills 1981b). The only instance of fouling by C. fluminea at the plant was during a test of the fire protection system in May 1981. Approximately half of the nozzels were blocked by small rocks and shells.

A density of 91.3 Corbicula fluminea/square meter was reported for Chickamauga Reservoir in TVA's response to I & E Bulletin 81-03 for the Sequoyah Nuclear Plant (Docket Nos. 50-259, 50-260, 50-296) (Mills 1981a). The only instance of fouling by C. fluminea at this facility was the discovery of a few shells in a non-safety related cooling condenser.

6.2.8 VIRGINIA (Fig. 12)

Diaz (1974) made the first report of Corbicula fluminea in Virginia. Specimens were taken in the James River between river mile 80, at Richmond, and river mile 45. He also found populations at the confluence of the Appomattox and James Rivers. Clams were usually found on clay silt substrata. Diaz (1974) suggested that the triclad, Dugesia trigrina may be a predator of C. fluminea in the James River estuary. Shell measurements indicated the James River was probably invaded by C. fluminea in 1968 or earlier (Diaz 1974).

Rodgers et al. (1977) reported the presence of Corbicula fluminea in the New River. In a later paper, Rodgers et al. (1978) calculated the upstream rate of invasion to be 14.4 km/yr. The population dynamics, ecology, and control of C. fluminea in the New River was discussed in detail by Cherry et al. (1980).

Corbicula fluminea has infested three fossil-fueled power stations in Virginia: the Twelfth Street Generating Station of the Virginia Electric and Power Company, Richmond (Diaz 1974); the Glen Lyn Power Plant (Rodgers et al. 1977, 1978; Graney et al. 1980; Cherry et al. 1980); and the Potomac Electric Power Company's generating station at Alexandria (Dressler and Corey 1981). C. fluminea has also been found in the collecting ponds of cooling towers at the Allied Chemical Company plant at

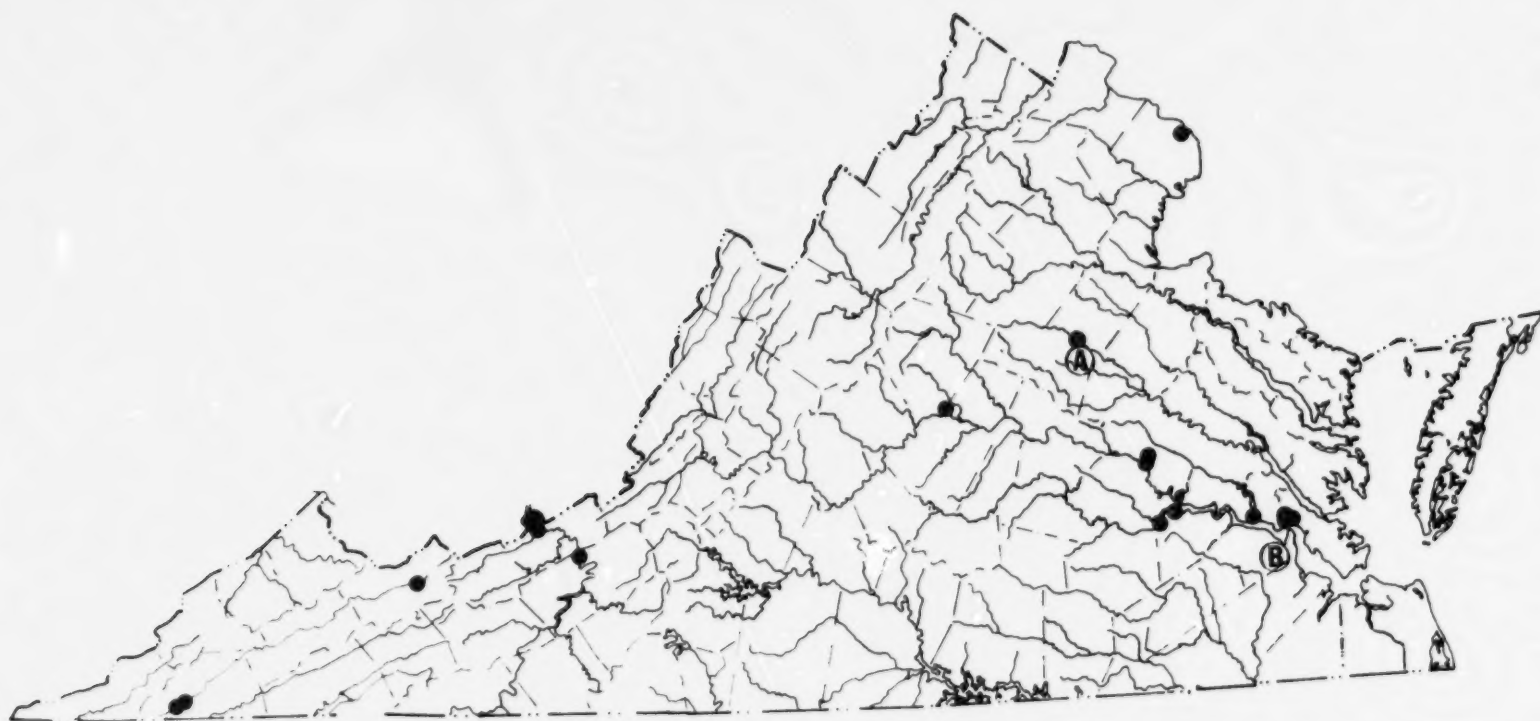


Figure 12. Zoogeographic distribution of Corbicula fluminea in Virginia. A = North Anna (OL); B = Surry (OL). Scale bar = 50 km.

Hopewell (Diaz 1974). The thermal effluent of the Glen Lyn plant has been implicated in the maintenance of a stable population in the New River (Rodgers et al. 1978, Graney et al. 1980).

The UD/CMS data base contains Virginia stream records for Corbicula fluminea as follows: Anna River, Appomattox River, Chickahominy River, Clinch River, James River, Lake Anna, New River, and Potomac River.

The response to I & E Bulletin 81-03 by North Anna (Docket No. 50-404) indicates that Corbicula fluminea has been present in Lake Anna since 1979 (Spencer 1981). It was also noted that the population has grown substantially since 1979 and that the clams are now the dominant benthic organism in terms of biomass. No instance of biofouling has been reported in Units 1 and 2 (Docket Nos. 50-338, 50-339) (Rains et al. 1984).

No fouling by Corbicula fluminea has been reported for Surry Power Station (Docket Nos. 50-280, 50-281) (Sylvia 1981). The absence of C. fluminea from the plant vicinity is attributed to the high salinity of the James River at the plant site.

6.3 REGION III

Corbicula fluminea has been found in seven states of Region III. These populations have been small and associated fouling of industrial facilities have been comparatively light. However, many of the C. fluminea populations in this region survive in thermal effluents from these facilities.

6.3.1 ILLINOIS (Fig. 13)

The oldest record of Corbicula fluminea in Illinois is that of Fetchner (1962) for Massac County along the Ohio River. Parmalee (1965) later reported the spread of C. fluminea in the Ohio River of Illinois and found specimens at 18 localities in the rivers and streams of the southern border counties including the Mississippi, Ohio, and Wabash Rivers. Parmalee believed that C. fluminea became established in the Ohio River in Illinois in 1961 and that populations in the three southern rivers of the state were descendents of populations from the Cincinnati Reach of the Ohio River (Kerr et al. 1964). Substrata for the Illinois populations reported by Parmalee varied from silt, sand and mud to slab like cobbles. However, densest populations were found in sand substrata.

Thomerson and Myer (1970) reported large populations of Corbicula fluminea inhabiting the cooling system of the Granite City Steel Company's plant at Granite City in 1969. The intake pipe for the plant's water system was at Lock and Dam 27 of the Chain and Rocks Canal of the Mississippi River. They believed C. fluminea became abundant at that site in 1966. Specimens from this locality were later used to determine the effects of potassium on larval and adult C. fluminea by Anderson et al. (1976).

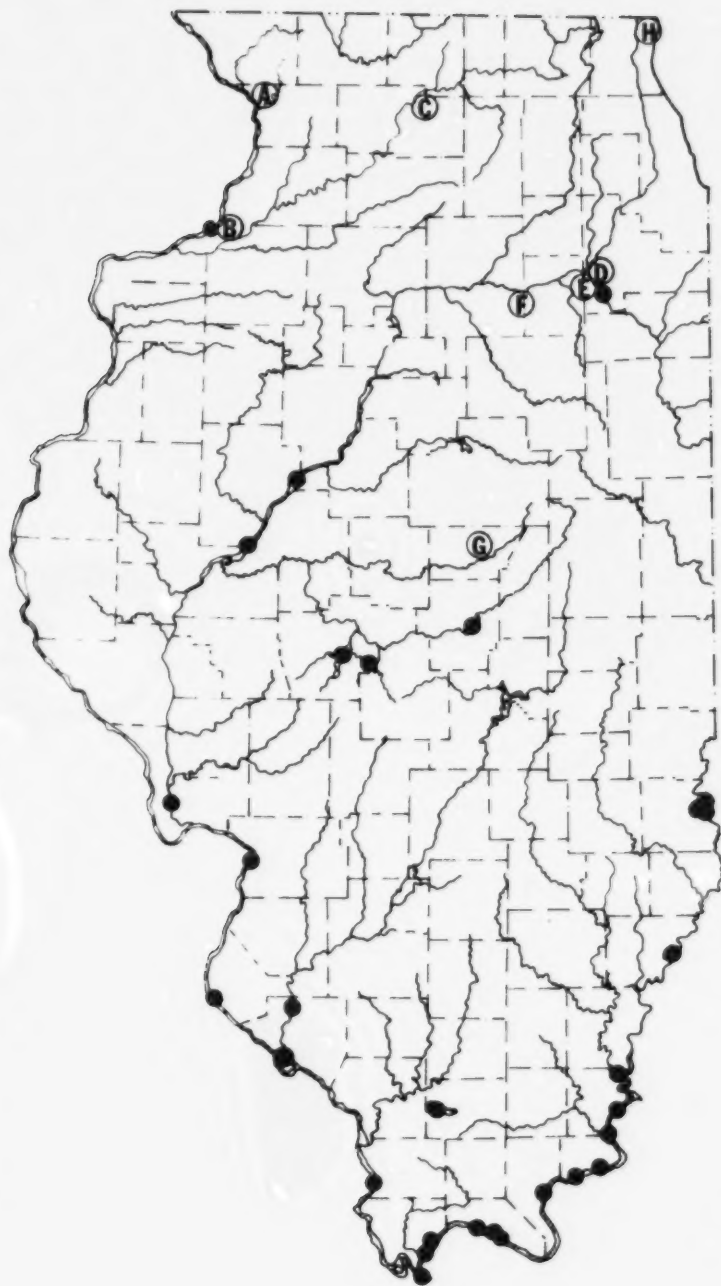


Figure 13. Zoogeographic distribution of *Corbicula fluminea* in Illinois. A = Carroll County (P); B = Quad Cities (OL); C = Byron (CP); D = Dresden (SD, OL); E = Braidwood (CP); F = LaSalle (OL, CP); G = Clinton (CP); H = Zion (OL).

Thompson and Sparks (1977) found populations of Corbicula fluminea in the Illinois River and noted that waters are generally warmer in areas where the bivalves are found. They believed the clams became established sometime between 1970 and 1971.

Klippel and Parmalee (1979) found that Corbicula fluminea were the most frequently recovered bivalve in Lake Springfield of the Sangamon River. Lake Springfield is an impoundment constructed in 1935 and C. fluminea probably became established there in the 1970's.

Lewis and Brice (1980) commonly found Corbicula fluminea in the Kankakee River. The location at which C. fluminea was abundant did not receive thermal discharge; a condition that has been credited with the success of the northern populations in Minnesota (Cummings and Jones 1978).

The fouling of several fossil-fueled power plants along the Illinois River has been reported (R. E. Sparks, personal communication 1984). Corbicula fluminea has been removed from the power plant at Havana during routine cleaning and have caused no shutdowns. A fouling event was also reported from the Commonwealth Edison plant at Rock Island where 40 cubic yards of C. fluminea shells were removed from the cooling tower basins and heat exchangers in April 1984 (M. Kline, personal communication 1984). Corbicula fluminea has also fouled the water system of the Catapillar Tractor factory at Peoria (R. E. Sparks, personal communication 1984).

A review of zoogeographic records for Corbicula fluminea in the UD/CMS data base reveals its presence in the following Illinois water bodies: Crab Orchard Lake, Dresden Lake, Illinois River, Kankakee River, Kaskaskia River, Lake Chautauqua, Lake Springfield, Mississippi River, Ohio River, Rice Lake, Saline River, Sangamon River, and Wabash River.

The response to I & E Bulletin 81-03 by the Dresden Nuclear Station (Docket Nos. 50-10, 50-237, 50-249) reported that Corbicula fluminea has been found in the source water bodies for the plant: Dresden Lake and the Kankakee River (Swartz 1981). Corbicula fluminea fouled heat exchangers of the following components of Unit 1's service water system: reactor enclosure cooling; turbine building cooling water, fuel handling building, hydrogen coolers, turbine lube oil coolers, waste vapor condenser, control room air conditioner, administration building air conditioner, access control building air conditioners, reactor enclosure air conditioning unit, and isolated phase building air coolers. Corbicula fluminea was also found in the main condenser of the circulating water system for Unit 1.

Corbicula fluminea was detected in the Dresden Units 2 and 3 cribhouse in March 1981 as live and dead clams. Examinations of all systems receiving service water and circulating water were conducted for both units. The heat exchangers of the following components in the service water system were found to be fouled by clams: offgas glycol chillers, offgas filter building air particulate vacuum pumps, concentrator condenser, control room air conditioner, auxiliary electric room air conditioner, turbine oil coolers, turbine building closed cooling water,

main generator hydrogen coolers, main generator stator coolers and set oil coolers, X-area coolers, containment cooling service water, standby diesel generator emergency air coolers (1 HPCI, 2 reactor building). The main condenser of the circulating water system was also fouled (Swartz 1981).

Quad Cities Nuclear Plant (Docket Nos. 50-254, 50-265) found many live and dead Corbicula fluminea in the intake structure and cribhouse area in April 1981 (Swartz 1981). Non-safety related equipment (turbine building closed cooling water heat exchangers, recirculation MG set oil cooler heat exchangers, turbine oil coolers, and hydrogen coolers) were fouled by small shells. Heat exchangers in the service building air conditioners were found to be blocked by C. fluminea shells in February 1981; this was the only major blockage reported at the facility.

Braidwood (Docket Nos. 50-456, 50-457) and LaSalle (Docket Nos. 50-373, 50-374) report Corbicula fluminea to be present in their source water bodies. No incidence of in plant fouling has been noted at LaSalle (Swartz 1981). Braidwood is under construction and will take makeup water from the Kankakee River.

Byron (Docket Nos. 50-454, 50-455), Zion (Docket Nos. 50-295, 50-304) stations, and Clinton Power Station (Docket Nos. 50-461, 50-462) have reported no infestations by Corbicula fluminea (Swartz 1981, Wuller, 1981) and lie outside of the present known zoogeographic limits of the species.

6.3.2 INDIANA (Fig. 14)

Fox (1969) reported Corbicula fluminea in the Ohio River of southern Indiana. No specific locality information was reported. Taylor (1982) collected C. fluminea in three of seven localities in Big Indian Creek, a tributary of the Ohio River. No other published reports of C. fluminea in Indiana are known.

A review of the UD/CMS data base shows Corbicula fluminea to be present in the following streams: Big Indian Creek, Blue River, Ohio River, Salt Creek, Stoney Creek, Wabash River, and White River.

The response to I & E Bulletin 81-03 by Bailly Generating Station Nuclear I (Docket No. 50-367) indicates Corbicula fluminea is not present in the vicinity of the plant (Shorb 1981). Construction of Bailly has been canceled. Marble Hill nuclear facility (Docket Nos. 50-546, 50-547) is being converted to a fossil-fueled plant and C. fluminea is present.

6.3.3 IOWA (Fig. 15)

The only report of Corbicula fluminea in Iowa is that by Eckbald (1975). It was found in the thermal effluent from an unnamed electric power generating plant on the Mississippi River at Lansing in 1974. Eckbald believed the oldest clams at this site were 2 years old. They reached a maximum density of 200/m² in some areas. This is the only record for Iowa in the UD/CMS data base.

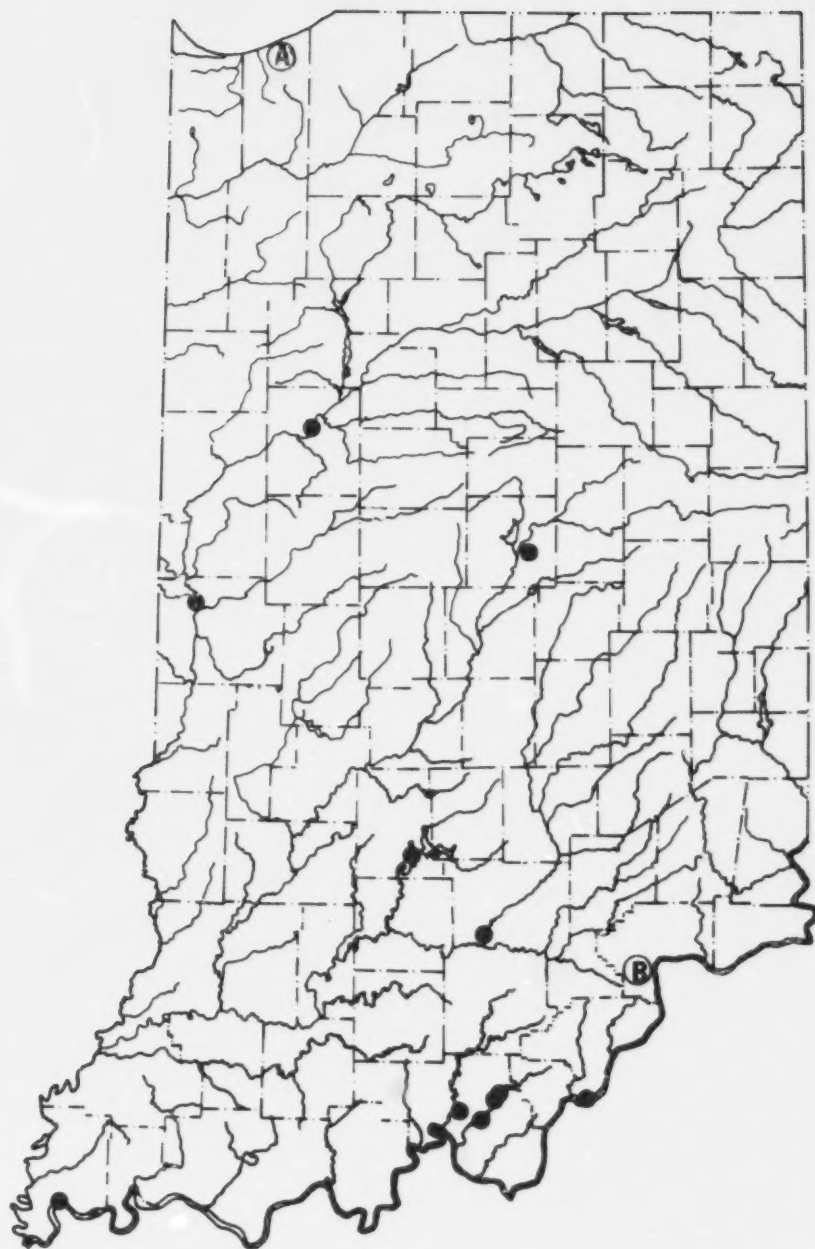


Figure 14. Zoogeographic distribution of *Corbicula fluminea* in Indiana. A = Bailly (CD); B = Marble Hill (CD). Scale bar = 50 km.

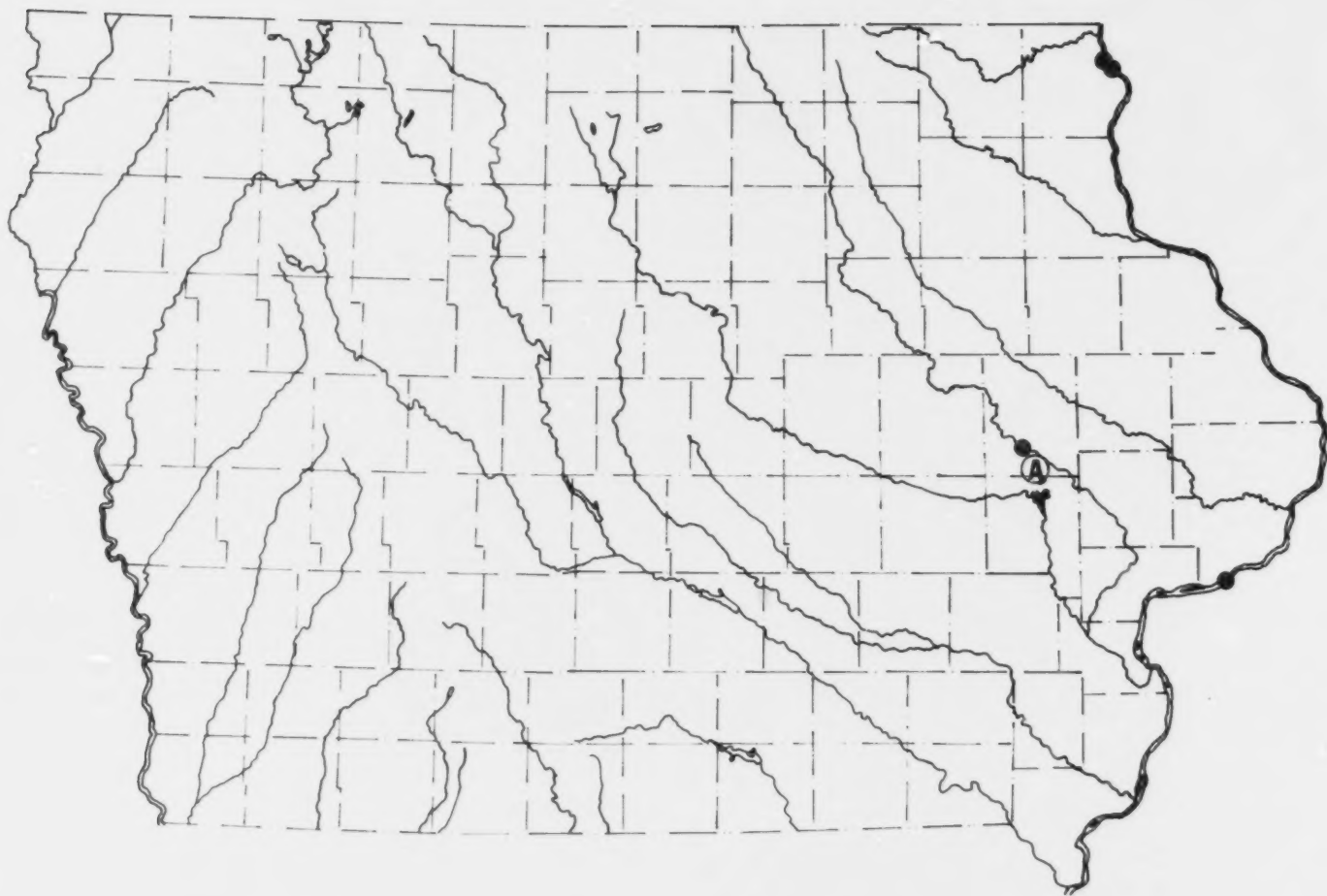


Figure 15. Zoogeographic distribution of Corbicula fluminea in Iowa.
A = Duane Arnold (OL). Scale bar = 50 km.

The response to I & E Bulletin 81-03 by Duane Arnold (Docket No. 50-331) indicated no fouling problems with Corbicula fluminea at the facility. The facility did note the collection of a single specimen of C. fluminea in the Cedar River in the vicinity of the Lewis Access, located approximately 4 miles upstream in January 1979.

6.3.4 MICHIGAN (Fig. 16)

The only report of Corbicula fluminea in Michigan is that of Clarke (1981). Specimens were found in Lake Erie on sand substratum in 1.3 m of water approximately 305 m south of the mouth of Sandy Creek. No other bivalves were found at this locality. Scott-Wasilk (Personal communication 1983) reported that these bivalves are living in the thermal plume of a power plant and have survived the winters since their discovery.

The UD/CMS data base contains several Michigan records for Lake Erie.

No instance of fouling by Corbicula fluminea has been reported by Big Rock Point (Docket No. 50-155) (Hoffman 1981), Cook Nuclear Plant (Docket Nos. 50-315, 50-316) (Hunter 1981), Midland (Docket Nos. 50-329, 50-330) (Cook 1981), or Palisades (Docket No. 50-255) (Hoffman 1981). These facilities lie outside of the present known zoogeographic distribution of C. fluminea.

6.3.5 MINNESOTA (Fig. 17)

Corbicula fluminea has been reported from only one locality in Minnesota. Specimens were found in a small lake that received thermal effluent from the Northern States Power Company's Blackdog Plant near Burnsville in 1978 (Cummings and Jones 1978). Other specimens were found in the channel of the Minnesota River downstream from the plant. Live specimens that were collected at these sites were approximately 3 years old. The shells, both live and dead, varied in height from 6 to 44 mm and were thought to represent individuals ranging in age from 1 to 5 years. Although the proportionately large number of empty shells suggested a mass mortality, no causative agent could be identified.

This is the only record for Corbicula fluminea in the UD/CMS data base.

No fouling by Corbicula fluminea was reported by Prairie Island Nuclear Generating Plant (Docket Nos. 50-282, 50-306) in their response to I & E Bulletin 81-03 (Gilberts 1981a). Similarly, no fouling by C. fluminea was reported for Monticello Nuclear Generating Plant (Docket No. 50-263) (Gilbert 1981). However, the response to the bulletin by this facility notes that "the presence of the Coon Rapids Dam located 30 mi. downstream (Mississippi River) of the Monticello Plant would effectively block orderly upstream migration (by attachment of clams to boats)". The transport of C. fluminea by attachment to boats has always been speculative and never proven. Further, dams have thus far offered no serious barrier to the dispersal of C. fluminea in streams (e.g. the Tennessee River [Sinclair and Isom 1963]). It is recommended that Monticello continue surveillance for these bivalves.



Figure 16. Zoogeographic distribution of *Corbicula fluminea* in Michigan. A = Big Rock Point (OL); B = Midland (CP); C = Palisades (OL); D = Cook (OL); E = Fermi (CP); F = Greenwood (CD). Scale bar = 50 km.

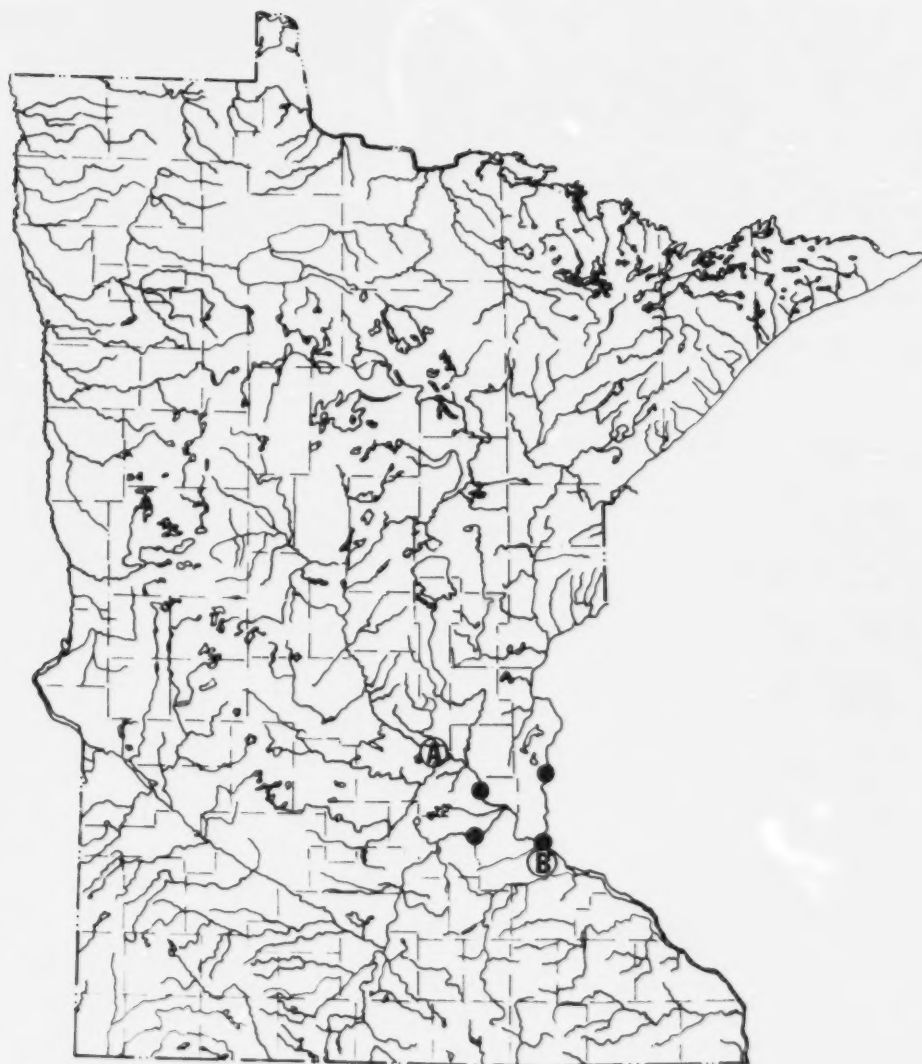


Figure 17. Zoogeographic distribution of *Corbicula fluminea* in Minnesota.
A = Monticello (OL); B = Prairie Island (OL). Scale bar = 50 km.

6.3.6 MISSOURI (Fig. 18)

Fox (1969) reported Corbicula fluminea from the Mississippi River. Oesch (personal communication 1979) found C. fluminea in the Big and Boureuse Rivers as well as in the Little Black River.

An examination of the UD/CMS data base reveals the presence of Corbicula fluminea in: Big Creek, Big River, Black River, Bourbeuse River, Bryant Creek, Cane Creek, Gasconade River, Little Black River, Little River Canal, Logan Creek, Meramec River, Mississippi River, Missouri River, Moreau River, Osage River, St. Francis River, Thomas Hill Reservoir and White Water River.

Callaway Units 1 and 2 (Docket Nos. 50-483, 50-486) located along the Missouri River, is still under construction and has not reported fouling problems with Corbicula fluminea.

6.3.7 OHIO (Fig. 19)

Pojeta (1963) first reported Corbicula fluminea in the Ohio River from collections made in 1962. Horning and Keup (1964) later reported the decline of the C. fluminea population in the Cincinnati Reach of the Ohio River. They attributed this mass mortality to the severe winter of 1962-1963 during which the river was ice covered for seven days. Keup et al. (1963) also noted the spread of C. fluminea above Cincinnati at RM 465.5. Three years later, C. fluminea had spread to Marietta at RM 172 (ORSANCO 1966). Taylor (1980) found C. fluminea along the entire length of the Ohio River from the Ohio-Pennsylvania state line to just below the mouth of the Scioto River near Greenup Locks and Dam.

Scott-Wasilk et al. (1983) reported Corbicula fluminea at 8 localities along the western shore of Lake Erie at the mouth of the Maumee River. Clams were found at the Acme Generating Station and the Bay Shore Generating Station of Toledo Edison. They attributed the survival of these bivalves to the continuously flowing thermal plume which keeps water temperature above 4.5 C in winter.

Fouling of the fossil fueled Gavin Power Station on the Ohio River, in Gallia County, has also been reported (S. B. Mills, personal communication 1984).

The UD/CMS data base contains records for the following Ohio streams and water bodies: Brush Creek, Clear Fork of the Muskingum River, Hocking River, Lake Erie, Licking River, Little Muskingum River, Maumee River, Meigs Creek, Miami River, Muskingum River, Ohio River, Olentangy River, Olive Green Creek, Scioto River, and Stillwater River.

Davis-Besse Nuclear Power Station (Docket No. 50-346), in its response to I & E Bulletin 81-03 (Crouse 1981) noted the presence of Corbicula fluminea in Lake Erie, which is the source and receiving water body for the facility. They also noted the presence of C. fluminea in the intake and overflow canal of Monroe Power Plant (Detroit Edison) where densities were 15/ft². However, no bivalves were found at Davis-Besse.

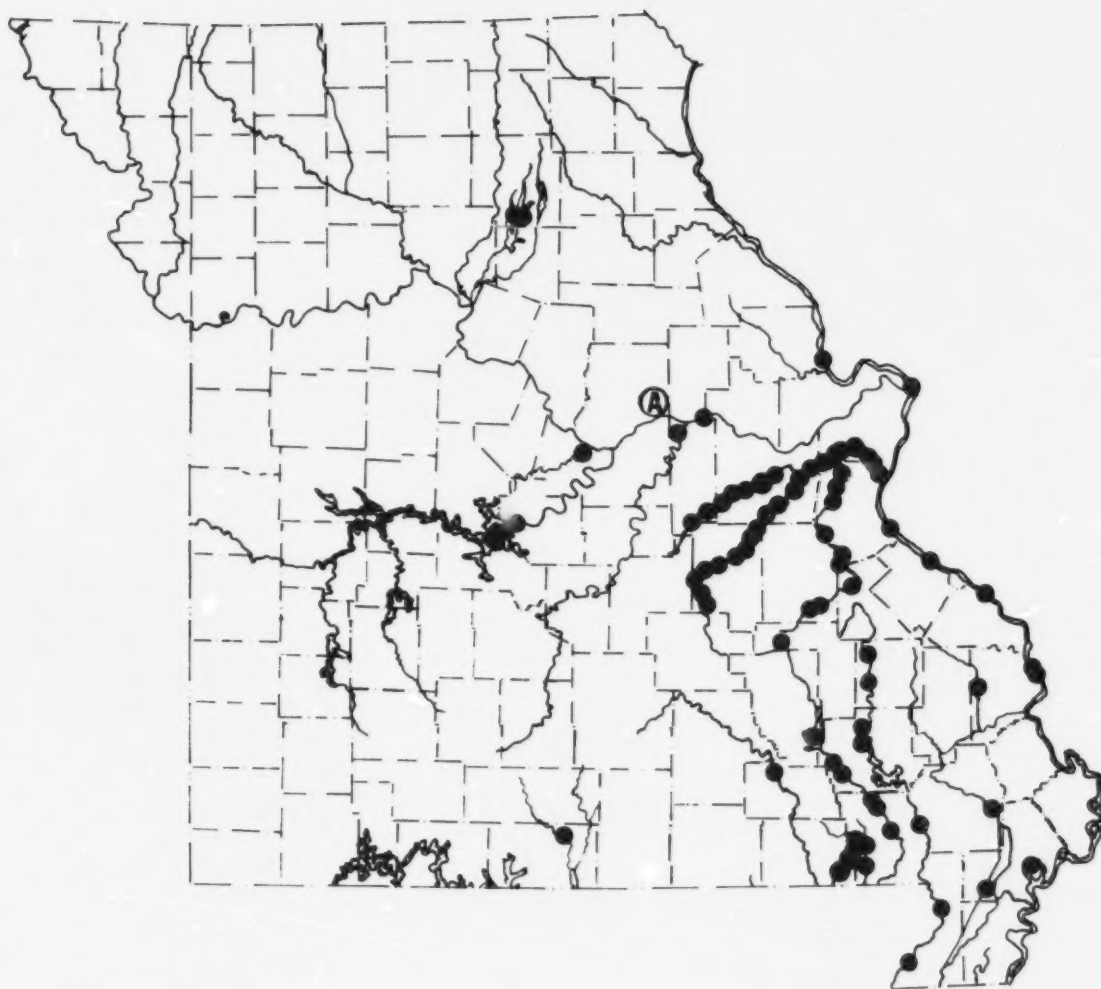


Figure 18. Zoogeographic distribution of Corbicula fluminea in Missouri.
A = Callaway (CP). Scale bar = 50 km.

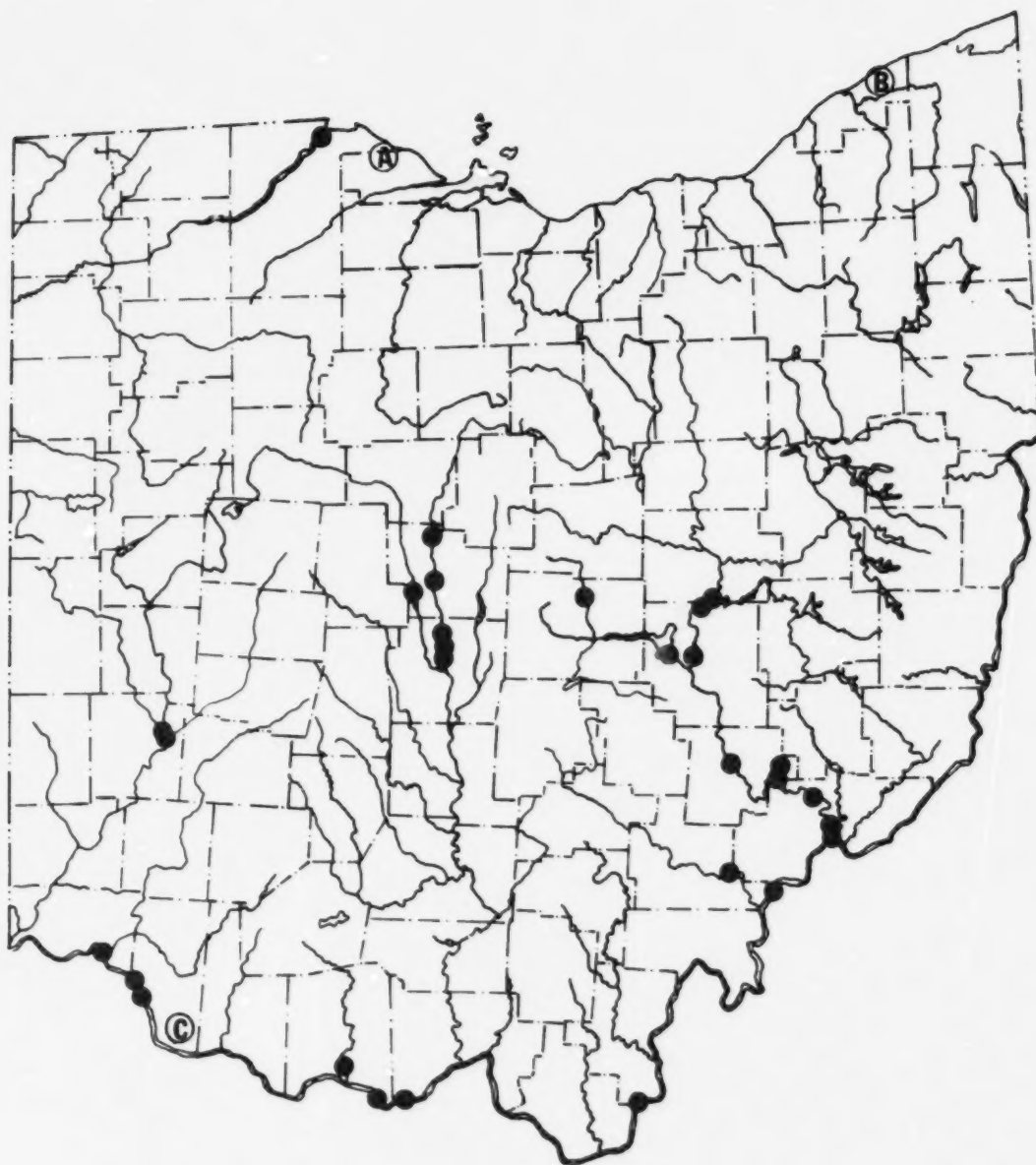


Figure 19. Zoogeographic distribution of *Corbicula fluminea* in Ohio. A = Davis-Besse (OL); B = Perry (CP); C = Zimmer (CD). Scale bar = 50 km.

Zimmer Nuclear Power Station (Docket No. 50-358) reported that Corbicula fluminea is a year-round resident of the Ohio River at the plant site (Borgmann 1981). They also reported minor shell debris in the service water system heat exchangers during construction activities. Construction plans for Zimmer have since been cancelled.

6.3.8 WISCONSIN (Fig. 20)

Corbicula fluminea was discovered in the St. Croix River in the summer of 1977 (Cummings and Jones 1978, Fuller 1978b, Mathiak 1979). This is the only locality, thus far, that has been reported for the state. Since these bivalves were not living in a thermal plume, it is not known whether they have survived the winters since their discovery. However, C. fluminea is well established in the Keokuk Pool of the Mississippi River (R. E. Sparks, personal communication 1984).

The UD/CMS data base contains records for Corbicula fluminea in Wisconsin from the Mississippi River and the St. Croix River.

Kewaunee Nuclear Power Plant (Docket No. 50-305) and Point Beach Nuclear Plant (Docket Nos. 50-266, 50-301) are both located outside of the known zoogeographic distribution of Corbicula fluminea and have reported no incidence of fouling (Mathews 1981, Fay 1981). LaCrosse Boiling Water Reactor (Docket No. 50-409) reported the presence of C. fluminea one mile downstream of the plant in the Mississippi River (Linder 1981). However, no bivalves have been found at or in the plant.

6.4 REGION IV

Corbicula fluminea occurs in three states of Region IV: Arkansas, Louisiana, and Texas. Other states in the region (Oklahoma, Nebraska, Kansas, and Colorado either do not have C. fluminea populations or nuclear power plants.

6.4.1 ARKANSAS (Fig. 21)

Fox (1970) reported Corbicula fluminea from the St. Francis River in the northeastern portion of the state where densities of these clams reached 21/yd². He also reported C. fluminea from the lower Ouachita River in the southwestern portion of the state. These were the first published reports of C. fluminea in Arkansas.

Kraemer (1976) found Corbicula fluminea in the Arkansas River at river mile 43. Kraemer (1977) later reported these bivalves at river mile 171 and said they were ubiquitous from below Ft. Smith downstream to Lock and Dam No. 3. Kraemer (1976) believed it unlikely that C. fluminea invaded the Arkansas River before the mid-1960's.

Corbicula fluminea has also been reported from the Buffalo River (Kraemer 1978, 1979), Chamagnoll Creek and the Caddo River (Britton and Morton 1979) as well as from the White River (Kraemer 1980).

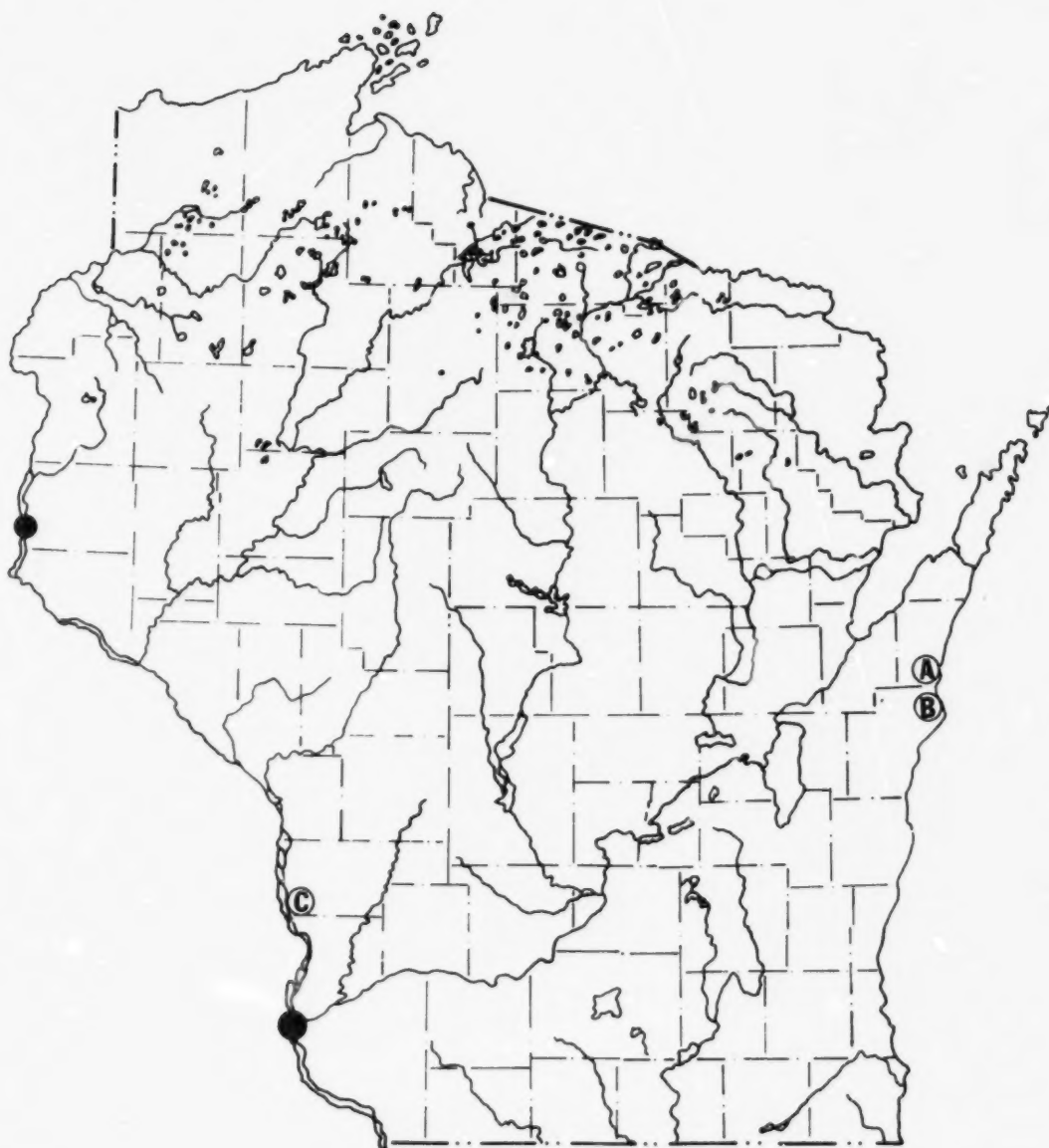


Figure 20. Zoogeographic distribution of *Corbicula fluminea* in Wisconsin.
A = Kewaunee (OL); B = Point Beach (OL); C = LaCrosse (OL).
Scale bar = 50 km.

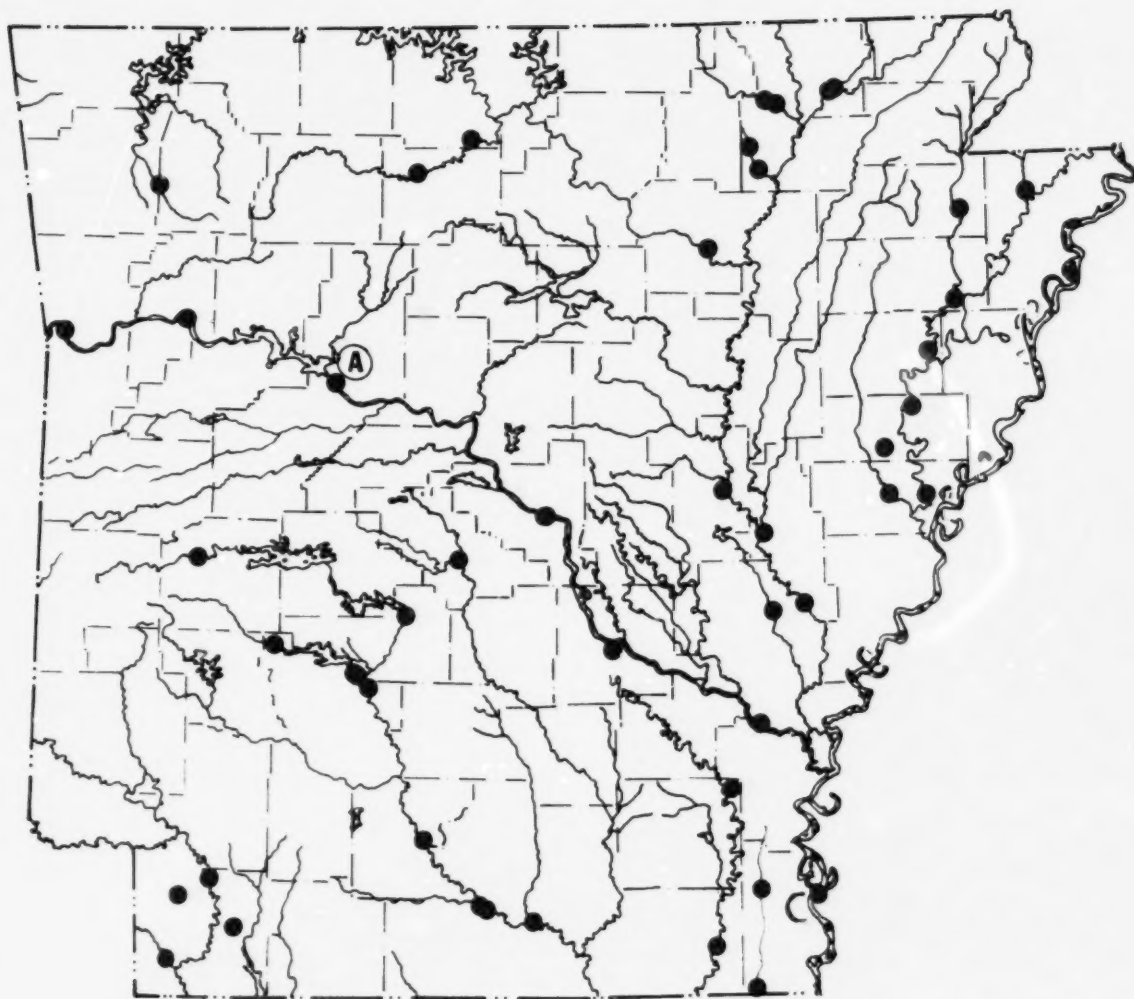


Figure 21. Zoogeographic distribution of *Corbicula fluminea* in Arkansas.
A = Arkansas Nuclear One (OL). Scale bar = 50 km.

Arkansas records for Corbicula fluminea in the UD/CMS data base include: Arkansas River, Bayou Bartholomew, Black River, Boeuf River, Buffalo River, Caddo River, Chamagnoll Creek, Coon Bayou, La Grue Bayou, L'Anguille River, Little River, Madison - Mariana Diversion Canal, Maniece Bayou, McKinney Bayou, Mississippi River, Ouachita River, Red River, Saline River, St. Francis River, Spring River, Strawberry River, and White River.

The fouling of Arkansas Nuclear One, Units 1 and 2 (Docket Nos. 50-313, 50-368) formed the basis for NRC's issuance of IE Bulletin 81-03 and the fouling of the plant is well described in the Bulletin.

6.4.2 LOUISIANA (Fig. 22)

Stein (1962) made the first report of Corbicula fluminea from Louisiana waters. These bivalves were collected in the Mississippi River in 1961. However, no precise locality data were published concerning these specimens and none accompanies the specimens collection label at the Ohio State University Museum of Zoology (OSUM 4416). Dundee and Harman (1963) found C. fluminea in benthic samples taken from Bayou Magasille and Bayou Sorrel in 1962.

Gunning and Suttikus (1966) found Corbicula fluminea throughout the lower Pearl River system and speculated, based on shell measurements, that it became established in the Pearl River in 1959. Corbicula fluminea was abundant in sand, gravel, silt, and mixtures of the substrate types in the Pearl River (Gunning and Suttikus 1966).

Kuckyr and Vidrine (1975) reported Corbicula fluminea to be the most abundant of 21 species of bivalves collected in the Tensas River of southern Louisiana. Vidrine and DeRouen (1976) found that C. fluminea inhabited most of the streams of the Bayou Teche system of southwest Louisiana.

Thompson (1983) reported on the presence of Corbicula fluminea in the coastal regions of Louisiana and the lower Atchafalaya Basin and noted that it is the principal food item in the diet of the American alligator, Alligator mississippiensis in that region.

Records for Corbicula fluminea in Louisiana waters in UD/CMS data base are: Atchafalaya Basin, Bayou Cocodrie, Bayou Magasille, Bayou Sorrel, Calcasieu River, Mississippi River, Pearl River, Red River, and Tensas River.

The response to IE Bulletin 81-03 by River Bend Station Unit 1 (Docket No. 50-458) indicated a low density of Corbicula fluminea (0-5/m²) at the intake embayment and in the Mississippi River in the vicinity of the plant (Booker 1984). They further reported two peaks of abundance (June and August) for samples of drifting larvae that reflects the bimodal spawning pattern observed in other southern United States streams. Adult and larger juvenile C. fluminea were more abundant on the western shore of the river.

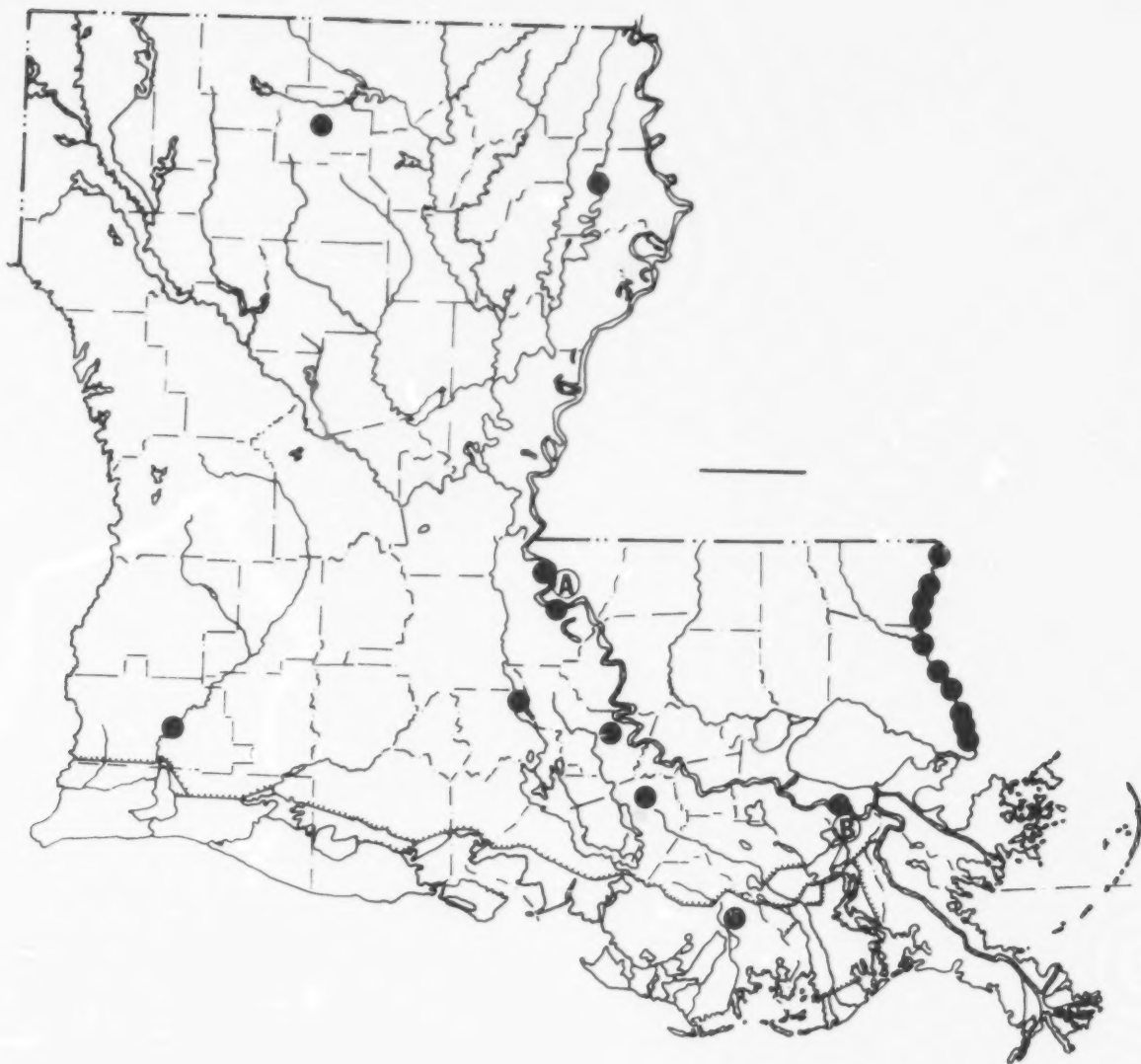


Figure 22. Zoogeographic distribution of *Corbicula fluminea* in Louisiana. A = River Bend (CP); B = Waterford (CP). Scale bar = 50 km.

Waterford Unit 3 (Docket No. 50-382) reported the presence of Corbicula fluminea and noted densities of these bivalves ranged from 0 to a little over 4000/m² in the vicinity of the plant site (Maurin 1981). Corbicula fluminea, along with aquatic worms, was the most abundant benthic organism in the vicinity of the plant.

6.4.3 TEXAS (Fig. 23)

Metcalf (1966) first reported Corbicula fluminea in Texas. This first population was located in the Rio Grande at El Paso. These bivalves were believed to have invaded the Rio Grande in 1964 or earlier (Metcalf 1966). Since its initial discovery, C. fluminea has extended its range downstream to Monte Alto reservoir and Falcon Lake (Murray 1971a).

Corbicula fluminea has also invaded the Colorado River system. Specimens reported from this river have nearly all been reported from reservoirs. Murray (1971b) reported C. fluminea from Lake Lyndon B. Johnson. O'Kane et al. (1977) reported infestations in Lake Inks and Lake Travis. Britton and Murphy (1977) found C. fluminea at Marble Falls.

Other populations of Corbicula fluminea in Texas have been reported from the Big Cypress River (Pool and McCullough 1979), the Blanco River (Horne and McIntosh 1979), the Brazos River (Britton and Morton 1979), the Concho River (Baker 1978), the Nueces River (Murray 1978), the Red River (Britton and Murphy 1977), the Sabine River (Pool and McCullough 1979), and the Trinity River system (Britton and Murphy 1977, McMahon 1977, Aldridge and McMahon 1978, Evans et al. 1979). Boone (personal communication 1979) also reported C. fluminea from the Perdarnales, San Antonio, and San Jacinto Rivers.

Three instances of fossil-fueled power plant fouling by Corbicula fluminea occurred in Texas (McMahon 1977, O'Kane et al. 1977, Baker 1978). In all three cases the infestations required the shutdown of the plant to remove the clams and restore normal operation.

Britton and Murphy (1977) reported that Corbicula fluminea is a food of the fishes Lepomis microlophus and Minytrema melanops in Lake Benbrook and Aplodinotus grunniens in Eagle Mountain Lake.

Hillis and Patton (1982) examined the morphology and genetic variability of populations in the Brazos River system. It was their opinion that two species of bivalves in the genus Corbicula may have been introduced into North America. Their evidence is, however, preliminary and they are unable to refer the presumed second species to a taxon with certainty. Britton (1982) reviewed the biogeography and ecology of C. fluminea in Texas and also discussed the possibility of two species being in the state.

Stream records for Corbicula fluminea in Texas contained in the UD/CMS data base are: Angelina River, Atacosa River, Big Cypress River, Blanco River, Brazos River, Clear Fork of the Trinity River, Colorado River, Concho River, Frio River, Geronimo Creek, Guadalupe River, Johnson

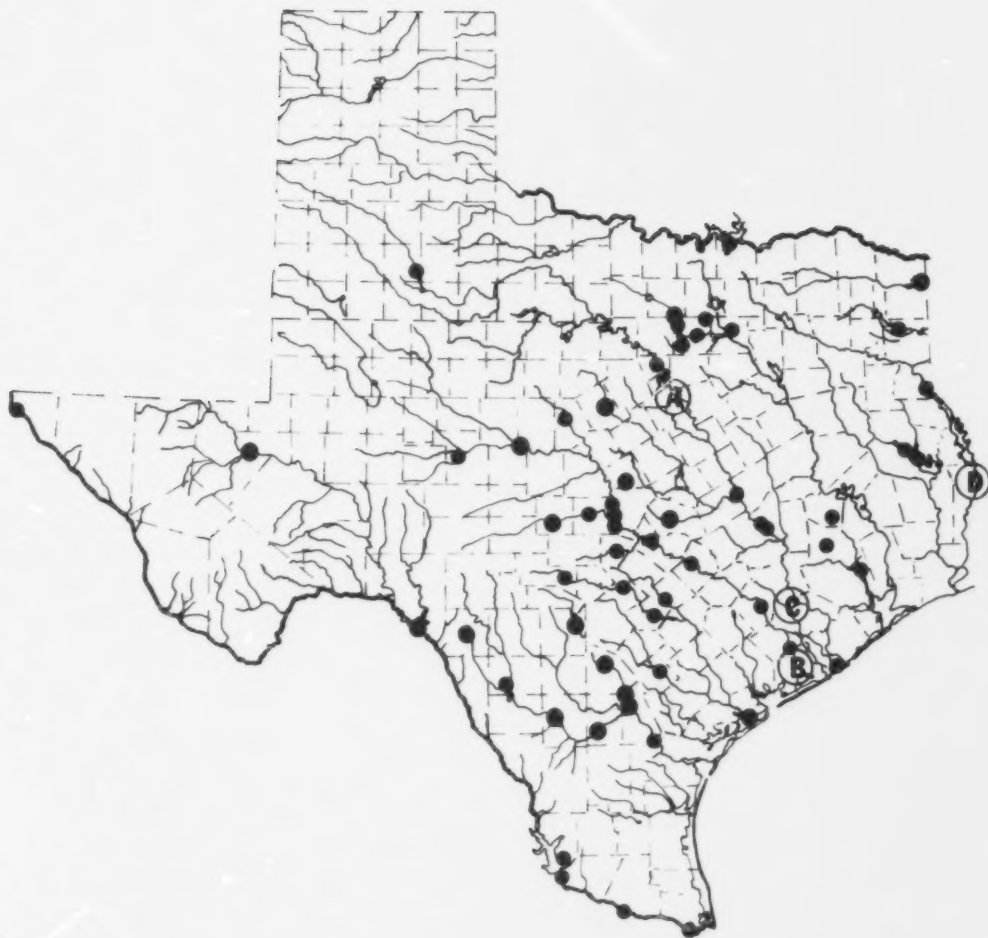


Figure 23. Zoogeographic distribution of *Corbicula fluminea* in Texas. A = Comanche Peak (CP); B = South Texas (CP); C = Allens Creek (CD); D = Blue Hills (CD). Scale bar = 50 km.

Creek, Lake Arlington, Lake Benbrook, Lake Granbury, Lake Grapevine, Lake Houston, Lake Inks, Lake Lyndon B. Johnson, Lake Thunderbird, Lake Travis, Leon River, Little Brazos River, Llano River, Medina Creek, North Lake Reservoir, Nueces River, Pecos River, Perdarnales River, Pinto Creek, Red River, Rio Grande, Sabine River, Sam Rayburn Reservoir, San Antonio River, San Gabriel River, San Jacinto River, Spring Creek, Sulphur Creek, Trinity River, and White River.

The response to IE Bulletin 81-03 by Comanche Peak Steam Electric Station (Docket Nos. 50-445, 50-446) reported no detectable populations of Corbicula fluminea in either Squaw Creek Reservoir or the Safe Shutdown Impoundment at the plant (Gary 1981). They did report, however, on the infestation of Texas Power and Light's DeCordova Bend Station, located on Lake Granbury and commented on the possibility of similar infestations at the Comanche Peak facility.

South Texas (Docket Nos. 50-498, 50-499) in their response to IE Bulletin 81-03, reported large numbers of Corbicula fluminea collected from the plant cooling reservoir in April 1981 (Goldberg 1981). They believed C. fluminea infested the region after the conclusion of their environmental monitoring program in 1974.

6.5 REGION V

The populations of Corbicula fluminea in Region V are the oldest in the United States. Four states in Region V have both nuclear power facilities and stream infestations by C. fluminea.

6.5.1 ARIZONA (Fig. 24)

Dundee and Dundee (1958) made the first report of Corbicula fluminea in Arizona from collections made at Papgo Park, Phoenix in 1956. Keup et al. (1963) later reported C. fluminea from Main Canal near Parker.

Minckley et al. (1970) found that Corbicula fluminea was a food of three species of buffalo fishes (Ictiobus bubalus, I. cyprinellus and I. niger) in Apache and Roosevelt Lakes in central Arizona. Veligers, juveniles, and small adults were consumed by these fishes. Rinne (1974) noted that the highest densities of C. fluminea in these lakes occurred on rock rubble slopes and increased directly with the complexity (numbers of components) of the substrata. He also noted that numbers of these clams increased with depth and position down lake from inflow areas with high turbidity.

Bequaert and Miller (1973) reported Corbicula fluminea to be common in the Colorado, Gila, and Verde Rivers by 1972. Dundee (1974) also reported C. fluminea from Lake Meade in the Colorado River drainage.

The UD/CMS data base contains Arizona records for Corbicula fluminea from the following waters: Arizona Canal, Auga Fria River, Colorado River, Consolidated Canal, Eastern Canal, Gila River, Lake Martinez, Parker Canal, Pleasant Lake, Salt River, South Canal, Southern Canal, Verde River, and various irrigation systems.

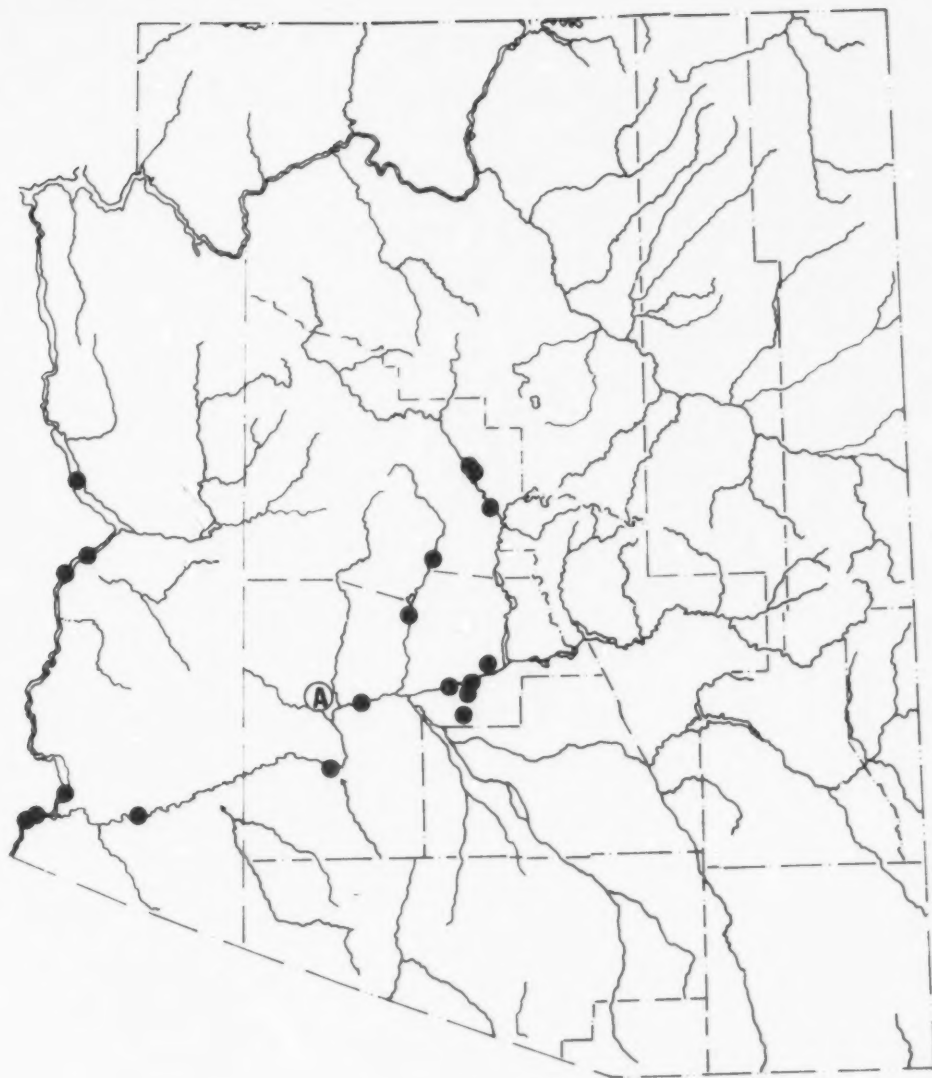


Figure 24. Zoogeographic distribution of *Corbicula fluminea* in Arizona.
A = Palo Verde (CP). Scale bar = 50 km.

The Palo Verde (Docket Nos. 50-528, 50-529, 50-530) response to IE Bulletin 81-03 indicated that no populations of Corbicula fluminea were present in the plant environment (Van Brunt 1981). They further noted that the plant will use treated sewage effluent as the source of cooling water. However, zoogeographic records for C. fluminea in Arizona indicate the presence of the species in the Gila River up and downstream of the plant site. Thus, the possibility does exist for the entrance of these bivalves into the plant. Further, C. fluminea has been used in studies of tertiary sewage treatment and has been found to survive in such waters (Haines 1979). Thus, the source waters of the Palo Verde facility should be monitored for the possible intrusion of C. fluminea.

6.5.2 CALIFORNIA (Fig. 25)

Corbicula fluminea was first discovered in California in the Sacramento River north of Pittsburg in 1945 (Hanna 1966). It apparently spread from this region to foul many of the canals surrounding the San Francisco Bay estuary and the Central Valley. It has been reported from Mayberry Cut and the Contra Costa Canal (Ingram 1959) and the South Bay Aqueduct (Morgester 1967).

Invasion of the Delta-Mendota Canal in the Central Valley has been well documented. Prokopovich and Hebert (1964) and Prokopovich (1969, 1970) noted that an increased deposit of clastic sediments was attributable to these bivalves binding suspended sediments with mucus and in their feces as well as decreasing water flow as a result of mounds of dead shells.

Eng (1975) reported on the biology of Corbicula fluminea in the Delta-Mendota Canal in a detailed study for the California Academy of Sciences. Eng (1976) also found the oligochaete, Chaetogaster limnaei von Baer, 1827, living and feeding on the lateral grooves of the gills of C. fluminea from the Delta-Mendota Canal. Of those clams examined in March 1974, 87% were infested. Less than 3% were infested in other months. These oligochaetes were believed to be commensal. In a later paper, Eng (1979) discussed the population dynamics and growth of these bivalves in the Delta-Mendota Canal. Behrens (1975) reported the survival and growth of these bivalves in beverage containers and, in one instance, a locked fishing tackle box, taken from the canal.

Sigfried et al. (1980) discussed the occurrence of Corbicula fluminea in the San Francisco Bay estuary in 1976 when conditions were dry. Corbicula fluminea dominated the benthos with the bivalve Macoma balthica, the amphipods Corophium stimpsoni and Corophium spinicoine, nematodes, and a spinoid polychaete, Boccardia ligérica. They determined that the factors controlling the size and composition of the benthos were salinity and sediment composition. They further reported that the population of C. fluminea peaked in March and noted that previous studies (Fisk and Doyle 1962, Hazel and Kelley 1966) showed population peaks in January. Their estimates of population densities for the estuary ranged from 2000/m² as compared with the 312/m² estimate of Fisk and Doyle (1962) for 1960-1961.



Figure 25. Zoogeographic distribution of *Corbicula fluminea* in California. A = Humboldt Bay (SD); B = Rancho Seco (OL); C = Diablo Canyon (LPTL); D = San Onofre (OL). Scale bar = 50 km.

Carlton (1973) discovered Corbicula fluminea in Stow Lake, Golden Gate Park, San Francisco. This represented the first detection of these bivalves on the peninsula.

Corbicula fluminea was discovered in the Imperial Valley of southern California in 1953 (Fitch 1953). It has since fouled many of the major aqueducts and reservoirs in this portion of the state including the Colorado Aqueduct (Fox 1970b), El Capitan Reservoir (Fast 1971), the Los Angeles Aqueduct (Fox 1973), the San Jacinto Reservoir (Fox 1972), Lake Jennings (Richardson et al. 1970), and Lake Matthews (Fox 1972). The Coachella Water District (Fitch 1953) and the Gene and Hayfield pumping plants of the Colorado Aqueduct have also experienced biofouling by C. fluminea. Fox (1970b) and Bequeart and Miller (1973) reported that the bivalve had infested the Salton Sea basin and had crossed into Baja, Mexico.

Richardson et al. (1970) noted that the blue catfish, Ictalurus furcatus (LeSueur) commonly fed on Corbicula fluminea in Lake Jennings. They did not believe, however, that I. furcatus would appreciably limit the size of C. fluminea populations where the two species are found together.

The UD/CMS data base for Corbicula fluminea contains records for the following California waters: Alamo Canal, All American Canal, Anaheim Bay, Brea Reservoir, Coachella Valley Water District, Cachuma Lake, Colorado Aqueduct, Columbia River, Delta-Mendota Canal, Dyer Canal, El Capitan Reservoir, Evans Lake, Folsom Lake, Kern River, Lake Casitas, Lake Jennings, Lake Murray, Lake Piru, Lincoln Park Lake, Los Angeles Aqueduct, Mayberry Cut, Merced River, Mokelumne Aqueduct, Mokelumne River, Natomas Reservoir, Outside Canal, Owens River, Park Lake, Potaroo Slough, Russian River, Sacramento River, Salinas River, Salton Sea, San Diego City Water Works, San Francisco Bay, San Jacinto River, San Joaquin River, San Luis Reservoir, Santa Ana River, Santa Barbara Harbor, Santa Margarita River, Shasta Lake, South Bay Aqueduct, Stanislaus River, Stow Lake, and Tolumne River.

San Onofre Nuclear Generating Station (Docket Nos. 50-206, 50-361, 50-362), in their response to IE Bulletin 81-03, indicated that Corbicula fluminea did not exist in the vicinity of the facility (Baskin 1981, Haynes 1981). They further reported that the source water for the fire protection system is freshwater tanks supplied by the domestic, treated water from the City of San Clemente. All cooling systems are supplied by sea water from the Pacific Ocean. It should be noted that an infestation of the San Diego Water Works (San Diego Museum of Natural History) has been reported and that monitoring of the fire protection system reservoir tanks at the San Onofre facility is warranted.

Rancho Seco (Docket No. 50-312) found no evidence of fouling by Corbicula fluminea (Mattimore 1981). They did note, however, that these bivalves are in the source waters (Folsom Lake, Natomas Reservoir) of their cooling water and have instituted a monitoring program.

Diablo Canyon (Docket Nos. 50-275, 50-323) and Humboldt Bay (Docket No. 50-133) are cooled by salt water systems.

6.5.3 OREGON (Fig. 26)

Although Ingram (1948) did not report Corbicula fluminea from Oregon, he did report the species as being collected along the north Bank of the Columbia River, Pacific County, Washington. Hence, it is not unreasonable to assume that C. fluminea was also present in Oregon during the 1940's. In a later paper, Ingram (1959) mentions populations in the Willamette River at the confluence with the Columbia River.

Fox (1969) noted that the entire Columbia River Basin of Oregon was infested and reported the presence of Corbicula fluminea in the Umpqua River for the first time.

Snow (personal communication 1979) noted that Corbicula fluminea is an important item in the diet of the white sturgeon, Acipenser transmontanus in Oregon.

Records of Corbicula fluminea in the UD/CMS data base for Oregon are: Columbia River, John Day River, Suislaw River, Smith River, Umpqua River, and Willamette River.

Trojan Nuclear Plant (Docket No. 50-344) reported the presence of Corbicula fluminea in the intake structure (Withers 1981). Clams were also found in the off-line bearing cooling water heat exchanger in water sediments deposited from the service water side of the condenser. The heat exchanger had been off line for approximately one year. No evidence of clams was found in the cooling tower basins or in the fire protection system.

6.5.4 WASHINGTON (Fig. 27)

The first report of Corbicula fluminea in the United States was made from collections on the banks of the Columbia River, Pacific County, in 1938 (Burch 1944). Ingram (1949) also reported C. fluminea from the north bank of the Columbia River near Knappton--the same population originally described by Burch (1944). Fox (1971), commenting on this discovery, noted that Burch's materials were composed of dead, drift shells and that the water of the Columbia River where they were collected is saline. Fox (1971) further reported C. fluminea in the Columbia River from near Knappton upstream to Richland.

Counts (1985) reported on the collection of Corbicula fluminea at Raymond, Pacific County, in 1937. Although no water body was specified in the collection locality description, it is assumed that these specimens are part of the general population of C. fluminea described by Burch (1944).

Records for Corbicula fluminea in Washington contained in the UD/CMS data base are for: Chehalis River, Columbia River, and Snake River.

Corbicula fluminea was found in the Columbia River approximately 5 miles upstream from the Washington Public Power Supply Nuclear Project facilities (Docket Nos. 50-397, 50-460) (Matlock 1981, Mazur 1981). No specimens were found in any of the structures or components of these facilities.

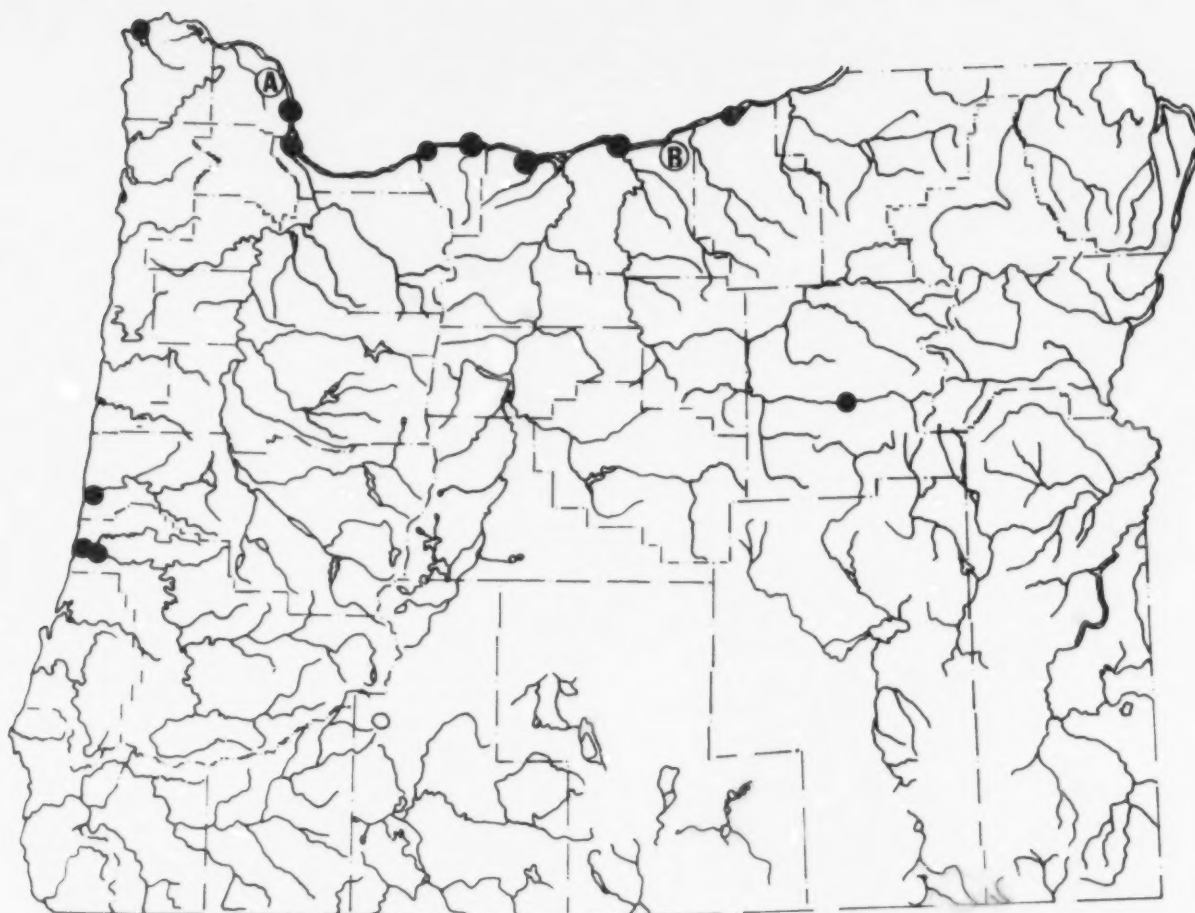


Figure 26. Zoogeographic distribution of Corbicula fluminea in Oregon.
 A = Trojan (OL); B = Pebble Springs (CD). Scale bar = 50 km.

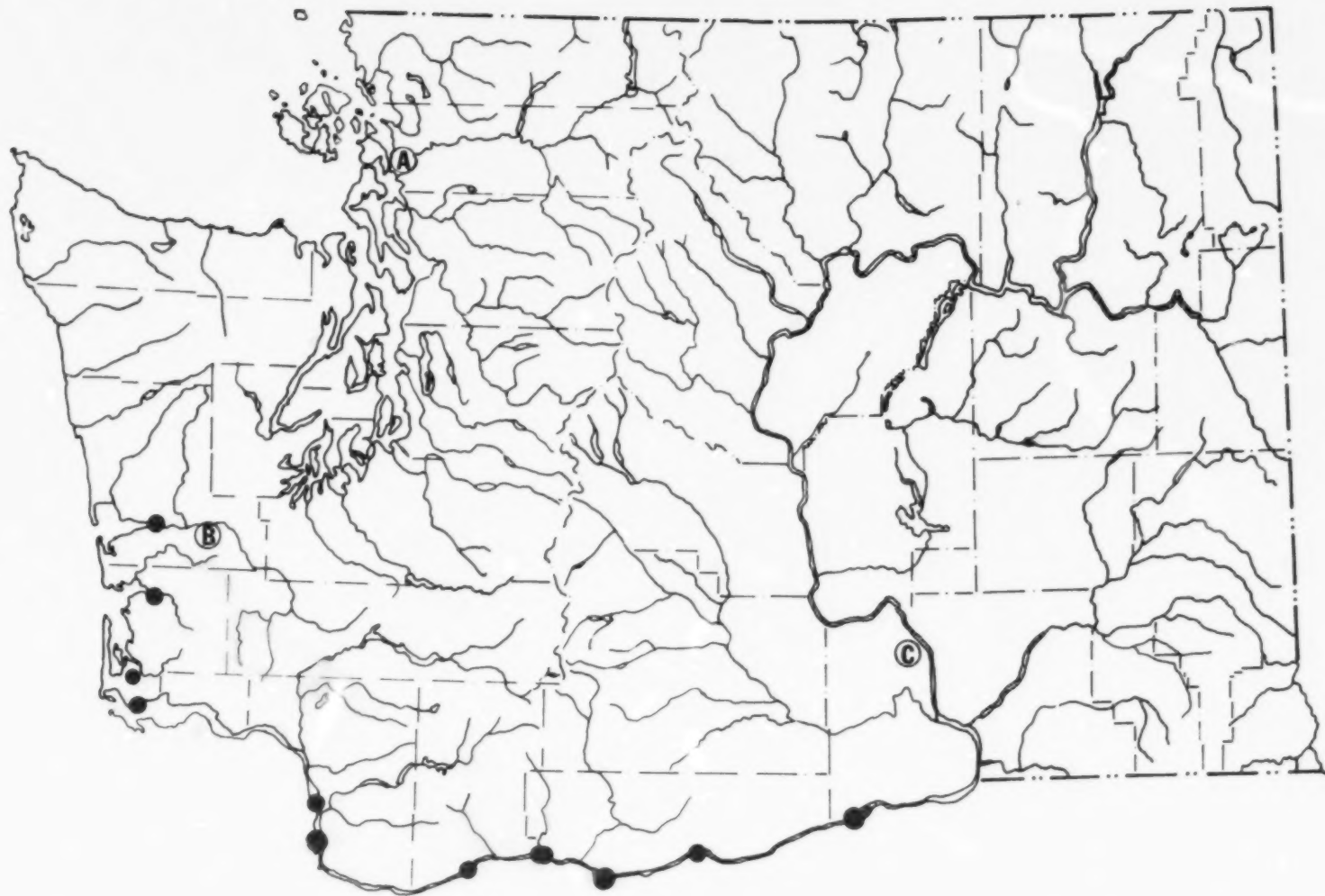


Figure 27. Zoogeographic distribution of *Corbicula fluminea* in Washington.
 A = Skagit (CD); B - WNP 3 (CP); 5 (CD); C = WNP 1 (CP), 2 (CP),
 4 (CD). Scale bar = 50 km.

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16. ABSTRACT (200 words or less) A review of the zoogeographic records for the exotic Asian clam, <u>Corbicula fluminea</u> (Müller, 1774), reveals its presence in 27 states where nuclear powered electric generating plants are either operating or under construction. Nineteen plant sites reported infestations of varying severity in facilities or source waterbodies immediately adjacent to the facility by populations of <u>C. fluminea</u> . Thirteen plant sites are located within the zoogeographic limits of <u>C. fluminea</u> but have a low risk of infestation due to either salt water cooling systems or locations a great distance from known populations. Eighteen plant sites are located wholly outside of the known zoogeographic range of <u>C. fluminea</u> . Thirty plant sites are located in close proximity to known populations of <u>C. fluminea</u> and therefore should maintain surveillance of the source water body and within plant water systems for possible infestations by these bivalves.					
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